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ANÆSTHETICS

THEIR

USES AND ADMINISTRATION

PLATE I.



Method of spinal injection (see p. 440). If these figures are looked at through a stereoscope, the exact position of the needle is well seen. (Sir J. Mackenzie Davidson has kindly taken these photographs.)

Frontispiece

ANÆSTHETICS

THEIR

USES AND ADMINISTRATION

BY

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PREFACE TO THE FIFTH EDITION.

SINCE the issue of the earlier editions of this book a material advance has been made in our knowledge of anæsthesia and analgesia ; while the older methods have become more accurate many new and valuable ones have been added to the anæsthetist's armamentarium. This has necessitated rewriting most of the old sections, deletion of obsolete apparatus and theories, and a considerable addition of new material. As illustrations render the letterpress easier of comprehension, especially when apparatus are concerned, a large number of photographs and woodcuts have been added. Eight full-sized plates have been inserted, some of which point out the position to be adopted by the patient and anæsthetist during certain methods, while others indicate the course and surface-marking of the direction of the principal sensory nerves and arm veins, thus facilitating the carrying out of regional analgesia and intra-venous infusion. The occurrence of the International Medical Congress in 1913 and the focussing of modern ideas on analgesia and anæsthesia in the subsection devoted to these subjects enabled me to obtain at first hand from the actual promoters of the more modern procedures the fullest and most reliable information.

Thus the procedures involved in giving nitrous oxide and oxygen in major surgery ; of ether by the open method, by intra-vascular infusion, by intra-tracheal and pharyngeal insufflation, and by colonic absorption ; the methods of

local regional and spinal analgesia, and the employment of alkaloids in analgesia and anæsthesia, have been introduced into and fully described in the present edition.

I have received great help from Dr. Teter, Dr. Ferguson, Professors Meltzer and Burkhardt, Dr. Crile, M. Tuffier, Dr. Braun, and from many of my fellow anæsthetists in this country, and to these workers I tender my thanks. I would also express my obligation to Mr. C. M. Page and Dr. Mennell in connexion with hedonal infusion, and to my colleague Mr. A. E. Barker for his most valuable assistance in preparing the section on Spinal Analgesia. Mr. L. Bathe Rawling has very kindly permitted me to use some of the plates from his book on "Landmarks and Surface-markings of the Human Body" to elucidate the directions given in dealing with regional and conductive analgesia. Messrs. Claudius Ash have laid me under great obligation by their courtesy both in making photographs and in lending blocks of instruments for my use. Many friends have been good enough to lend drawings depicting apparatus invented by them. I have also to acknowledge material help from Dr. A. Beresford Kingsford in reading proof-sheets, and from Mr. Gwynne Williams, who assisted me with the section on Local and Regional Analgesia; also from Mr. R. R. Bennett, who has revised the pharmacological notes.

The original plan of the book was to attempt to teach firstly that a correct knowledge of the physiological action of anæsthetics is essential for the novice who aspires to become a scientific, as opposed to a mere mechanical, anæsthetist; and secondly to inculcate the essential importance of learning how far physiological action is modified when the patients suffer from conditions which are pathological. The choice of the anæsthetic, the selection of the method, and the adept employment of the latter according to the necessities of the patient and the operation can never be achieved by a mere rule-of-thumb system, so that I have

striven to present to learners a scientific, rather than a haphazard, way of attacking the most intricate subjects of analgesia and anæsthesia. That this is necessary can be readily seen by glancing over many of the resumé's of anæsthetics given in current works on surgical procedure, resumé's which, however well intentioned, cannot but mislead students of anæsthesia. They suggest simple methods and decry scientific ones, ignoring that the former are often instinct with danger, except in the hands of experts, and that the latter are only difficult to those who have not mastered the essential technique.

As it is true that the cruder surgical methods of a generation ago were simpler than the more scientific procedures of to-day, so is it beyond dispute that the routine haphazard systems of giving anæsthetics before anæsthesia became a science were free from elaboration, but also not exempt from serious peril. We have at least learnt to know what are the dangers of anæsthetics, and recently it has been shown us that by a judicious choice and by modern methods of employing analgesics and anæsthetics we can practically eliminate most or all of these dangers. If we prefer to ignore knowledge and servilely adhere to exploded theories and methods proved to be at once dangerous and unscientific, we sin against light and knowledge.

The aim of this book is to help those who desire to learn not only routine methods, but the wider knowledge, the more scientific art. The ambition is a wide one, and I appreciate how impossible it is within the narrow compass of a small manual to do justice to all views and all methods, but I hope that the attempt may be so far successful as to enable the conscientious student to prepare himself for practice, since by practice alone can he make himself a scientific anæsthetist.

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ANÆSTHETICS.

INTRODUCTION.

THE experience gained in teaching the principles underlying the safe use of anæsthetics in surgical practice has led the author to believe that the following preliminary remarks may prove of service.

In primis, even at the risk of offering superfluous advice, it is urged upon those who hope to acquire proficiency in the use of anæsthetics that unless they realise to the full the responsibility which must be assumed by the anæsthetist, they will never attain to even the foundation of their art. The timid and the reckless are equally dangerous, the one because he has no faith in his knowledge, the other because he has never realised that his skill and knowledge alone stand between his patient and peril, possibly death.

Whatever apparatus is employed, it should be personally examined before use, and the anæsthetic employed should be smelt before being placed in or upon the inhaler. The armamentarium of the anæsthetist should consist of the inhaler selected, an adequate quantity of the anæsthetic which has been chosen as most suitable for the patient, and if the particulars of the case are not known, an alternative anæsthetic, with appropriate apparatus; a gag, tongue forceps, sponges with holders, a mouth opener, tracheotomy instruments and intubation tubes, as well as a solution of strychnine, pituitary extract, morphine, atropine, digitaline, with a hypodermic syringe, should be at hand. In cases in which special dangers are apprehended additional aids are required, such as a cylinder of oxygen, a bellows fitted with india-rubber tubing, for pulmonary perfusion. All instruments, rubber bags, and face-pieces should be carefully and

thoroughly cleansed before and immediately after use. In cold weather the rubber of tubes and face-pieces should be rendered pliant by warming in hot water.

The terminology of the subject may be referred to in this place. Narcosis is used to connote the effects upon the patient caused by his blood and tissues being brought under the influence of alkaloidal bodies, such as morphine, and of anæsthetics, such as chloroform. It is obvious that these effects must vary according to the amount and strength of the agents employed, and so they are grouped in "degrees of narcosis." Five of these were recognised by Snow, and although the division is empirical, this division is useful, and is adopted in the present book. The French physiologists make three degrees of narcosis, since they consider the deeper narcosis following anæsthesia is toxæmic. The five degrees of Snow embrace the effects following the initial action of an anæsthetic up to the final catastrophe—death. Practical anæsthesia is concerned with the first three; the last of these is true surgical anæsthesia, which is a definite state, and cannot be spoken of as light or deep, since light anæsthesia really means the antecedent (second) degree of narcosis, while deep anæsthesia means a profounder narcosis (fourth degree) than exists in the state of anæsthesia (third degree). It is perfectly true that the depth of narcosis at the commencement of the third degree is less than at the end, but to avoid confusion, this variation in depth should be associated with the term narcosis, while anæsthesia is reserved to denote merely a condition in which the patient is unconscious of pain and ideationally unaffected by stimulation of sensory nerves.

Analgesia is restricted to the condition which is present when, although the patient is conscious, yet, owing to the local action of some drug, the sensory nerves or sensory nerve-roots of a particular area do not conduct sensory stimulation to his brain, so that he experiences no pain when trauma is inflicted on the area rendered analgesic.

Nomenclature of apparatus and methods.—The terms "closed," "open," "semi-open," "semi-closed," when applied to ethyl chloride, ether, and chloroform, are not strictly accurate, but as they have gained currency it has appeared best to adopt them rather than to introduce new terms. By

"open," as applied to masks, is meant a method which involves the use of a frame or mask, covered with some open meshed material, such as gauze, with domett or lint. If any air-tight covering is added, such as thin rubber, a rolled towel, oiled silk, or oiled paper, the method becomes a "semi-open," although it is in some instances a closed method to all intents and purposes.

"Closed" methods are understood to be those in which a cone or inhaler is used, and the patient inspires through tubes and at times breathes to and fro into a closed bag.

Chloroform inhalers are conveniently described as "dosimetric" when they enable the anæsthetist to control accurately the strength of the vapour presented to the patient. The supply may be aspirated by the patient's own inspiratory effort—and this is the "draw-over" system; or an atmosphere may be pumped by a motor into a face-piece or bag from which the patient breathes—and this is the "plenum" system. Two methods are commonly pursued in supplying the anæsthetic to open masks; "dropping," when it is allowed to fall drop by drop, and douching, when it is poured on the mask a drachm or more at a time—this is the "douche" method.

CHAPTER I.

HISTORICAL.

MEANS for producing surgical anæsthesia were practically unknown until Wells introduced nitrous oxide, Crawford Long employed ether, and Simpson chloroform. With the first employment of these three agents commences the history of artificial anæsthesia, although from very early times attempts were made to obtain insensibility during surgical operations.

Nepenthes or sedative draughts to relieve severe pain are mentioned in the *Odyssey*—Helen seeking to “drown all sense of woe” and to assuage the sufferings of Menelaus by such means. In Egypt, cannabis indica, the modern hashish, and other drugs, were similarly used. The “wine of the condemned” spoken of by the seer Amos was held by Simpson to have been derived from cannabis indica. Both among the Chinese and the Jews narcotics were given to criminals to alleviate the agonies of their death struggles. The Assyrians and Chinese seem to have employed various drugs with a view to relieve the anguish of wounds and of such rough surgery as was practised among them. Dr. Dudgeon, of Peking, however, gives little credence to the somewhat exaggerated narratives which have appeared concerning the extent to which anæsthesia was practised among the Chinese.

Opium, cannabis indica, carbon dioxide, and deadly nightshade, were advocated in various forms to achieve this object. Pliny and Dioscorides describe several methods in vogue among the Romans and other nations for benumbing parts subjected to incision and cauterisation. Memphis marble as a local anæsthetic, for example, was finely pow-

dered and applied to the part, and on the addition of vinegar a gas was given off (carbon dioxide) which rendered the part slightly anæsthetic. Various members of the Euphorbiaceæ, Mandragora, and other Solanaceous plants, were also employed in infusions, which on being drunk induced some narcotism. Sir Benjamin Ward Richardson prepared a draught from some *Atropa Mandragora*, following the directions given by Dioscorides, and stated that he found the potion a satisfactory anæsthetic. Attempts at anæsthesia by inhalation were very early practised. The Scythians burned *cannabis indica* and inhaled its fumes to alleviate pain. Snow has, however, pointed out that most of the drugs, the fumes of which were supposed to induce anæsthetic sleep, were really non-volatile, so whatever effect was produced must have arisen from the evaporation of the spirit used in preparing the solutions.

Many cases are recorded in the old writers—to wit, Paris and others—in which the fumes of the dry plant had analgesic effects.

The following passage occurs in Burton's "Arabian Nights," vol. ii. p. 26 : "'Thy rede is right,' quoth the King, and seeking his treasury he took then a piece of concentrated Bhang ; 'if an elephant smelt it he would sleep from year to year.'" Burton writes (footnote, p. 27) : "Here the Bhang (almost a generic term applied to hellebore, etc.) may be *hyoscyamus* or *henbane* [*sic* ?]. Yet there are varieties of *Cannabis*, such as the *Dakha* of South Africa, capable of most violent effect. I found the use of the drug well known to the negroes of the Southern United States and of the Brazil, although few of their owners had ever heard of it."

Mandrake. — Gerarde's "Herbal," Norton's ed. 1597, p. 282 : "The smell of the apples (mandrake) moveth to sleep."

Hellebore. — Woodville's "Medical Botany," vol. ii. p. 275, ed. 1790 : "Hippocrates frequently mentions Hellebore simply, or generically, by which we are told the white is to be understood, as he adds the word black or purging when the other species is meant."

In more modern times little advance was made until the last century. Most surgeons were contented to put their patients deeply under opium. Many "Drowsy Syrups" were

employed in the middle ages. The celebrated "Spongia Somnifera" of Hugo of Lucca, a Tuscan physician, his son Theodoricus of Lucca (1298), who was a monk, described as consisting of opium, hyoscyamus, cannabis indica, mulberry, mandragora, conium, wood ivy, lettuce, and water hemlock. Boccaccio, Shakespeare, and other writers frequently refer to potions given to dull the senses while amputations, etc., were performed. Such a draught was, it is said, given to Augustus, King of Poland, by his favourite surgeon, Weiss (1782), without the monarch's knowledge, so that the royal foot could be removed without pain.

In 1661, Greatrakes, a professional "stroker," practised anæsthetic mesmerism. He exploited his art before Charles II. In a MS. dated twenty years later, one Denis Papin wrote that he possessed the means whereby he could abrogate all painful sensations during a surgical operation, but what his method was was left unexplained.

In the sixteenth and seventeenth centuries Valverdi and others operated upon patients stupefied by compression of the carotid arteries, so depriving the brain of blood. In this practice they seem to have been anticipated by the Assyrians, who are reported to have compressed the vessels of the neck to render painless the operation of circumcision. James Moore, an English surgeon, in 1784, revived a suggestion, originally made by Ambroise Paré, that compression of the nerve-trunks should be practised before cutting the areas supplied by them, and John Hunter actually took advantage of the plan, and amputated a leg in St. George's Hospital after firmly compressing the crural and sciatic nerves. Wardrop (1832) proposed to operate upon patients rendered unconscious by bleeding them until syncope resulted. Richerand and other surgeons adopted the plan of rendering their patients intoxicated before applying the knife.

A departure in an entirely new direction was made by Mesmer and his followers, who averred that patients thrown into the "magnetic state" (*i.e.* hypnotised) could be surgically treated without any pain or inconvenience. Long before Mesmer lived, a belief had been current that the natural magnet possessed powers which were both curative of disease and capable of establishing anæsthesia. Thus Cardan (1584)

recounts how the magnet could be employed to abolish pain. The germs of the facts now known and accepted under the terms animal magnetism and hypnotism bore a fruitful harvest of windy words, Paracelsus, Glucenius, Burgrave, and others, contributing largely thereto. By Anthony Mesmer (born 1734), however, the matter was advanced from theory to practice, and although we may gird at Mesmer for a charlatan and a quack, we must accord to him a meed of gratitude for establishing upon a practical basis a theory which before his age was lost in useless verbiage. In 1776, Mesmer published his work, "The Influence of the Planets in the Cure of Disease," which maintained that the celestial orbs exercised, by means of "animal magnetism," an all-pervading fluid, an influence benign or malign on human beings. Fourteen years later, in conjunction with a Jesuit, called Father Hell, Mesmer undertook the cure of disease at first by means of the magnet and steel "tractors," but finally by means of the manual passes. The plaudits which at first greeted Mesmer in Vienna were ere long changed for the most hostile treatment, the learned bodies of his own and other countries treating his writings with contempt and himself with contumely. Leaving Vienna, Mesmer exploited Paris, and here he founded the widely famed hospital whereat he treated a great number of patients. In 1785, a Royal Commission was appointed to inquire into Mesmer's pretensions, but this and subsequent Commissions unfortunately confused the issues in question, and while they decided that Mesmer and his immediate adherents were unworthy of credence, they failed to recognise the substratum of truth underlying their teaching and practice. After Mesmer's downfall the subject was kept before the world by the practice of the Marquis de Puységur and the somnambulists. In 1829, Cloquet amputated a breast, the patient being rendered insensible through having been thrown into the hypnotic state. Elliotson, a firm believer in the practical uses of animal magnetism in surgery, employed it on several occasions with success. Braid, of Manchester, in 1841 made considerable trial of what he called the "neurohypnotic trance" as a means of producing surgical anæsthesia. Similar experiments were carried out in India by Dr. Esdaile, who

performed no less than three hundred operations upon patients in the hypnotic state. Ephemeral attempts have been made from time to time to revive the practice of hypnotism for the induction of anæsthesia with but partial success. It has been found that while only a certain number of persons are capable of being completely hypnotised, even these, as a rule, require many sêances under the hands of the magnetiser before the requisite degree of insensibility to pain is attained. Again, the mental state thus called into existence is in a large number of cases highly prejudicial to physical and moral well-being, and hence the consensus of opinion at present is rather adverse to the employment of hypnotism in anæsthetic practice, save in very exceptional circumstances and under carefully guarded conditions.*

In the eighteenth century the history of discoveries concerning anæsthetic methods becomes merged in that of the progress of chemical research. Hales, Lavoisier, Priestley, and Cavendish, opened up rich stores of knowledge by their discoveries in connexion with the gases. Oxygen, nitrogen, nitric oxide, were prepared and closely studied, and, in 1772, Priestley added nitrous oxide gas to the list. Pneumatic chemistry, till then unknown, became the absorbing theme among chemists, while physicians sought to bring the recent discoveries to account by pressing these gases into the service of medicine. Dr. Beddoes in 1798, assisted with finances by Wedgwood, the renowned potter, inaugurated his Pneumatic Institution at Clifton, where he proposed to treat phthisis and many other diseases by inhalations of various gases.

The Pneumatic Institute is interesting mainly because its first superintendent was Humphry Davy, who prosecuted therein his researches concerning nitrous oxide and other gases. In 1799, Davy discovered that "as nitrous oxide, in its extensive operation, appears capable of destroying physical pain, it may probably be used with advantage during surgical

* Prof. Grainger Stewart (*Lancet*, Oct. 21, 1893, p. 1018) said: "In every case hypnotic treatment involved hazard to the nervous system, and that those who were most susceptible to its treatment were the most apt to suffer, and that though it might free the patient from one set of symptoms it was apt to make him the victim of many others."

operations in which no great effusion of blood takes place." Davy substantiated his statements by most careful experiments upon the lower animals, extending Hales' research, which had been confined to mice, and demonstrating many facts, the practical uses of which were not appreciated for more than forty years later. But his philosophic mind did not content itself with limiting his experiments here; he actually inhaled the gas and found its influence to assuage the pains of toothache, and in his "Researches" are recorded his own sensations and the behaviour of others after inhaling nitrous oxide gas. Early in the nineteenth century, Henry Hill Hickman,* a young surgeon practising at Ludlow, in Shropshire, undertook experiments upon the lower animals with the hope of finding a means of avoiding pain during surgical operations. He investigated asphyxia, inhalations of carbonic acid gas and nitrous oxide, and performed operations on the animals while they were unconscious. His pronouncements were communicated to the profession of England and were received with incredulity and ridicule. An appeal to the French Academy of Medicine met the same fate, and poor Hickman, a veritable pioneer, died brokenhearted at the age of 29 (1829).

The discovery of the action of nitrous oxide made by Humphry Davy was not brought within the field of practical application until Horace Wells, a dentist of Hartford, Connecticut, conceived the idea of using nitrous oxide gas as an anæsthetic for tooth extraction. Wells went to a popular lecture delivered before the inhabitants of Hartford by a Mr. Colton, an itinerant lecturer on chemistry. During the performance one of the audience inhaled an impure sample of nitrous oxide and became very excited. In the course of his gyrations this individual wounded his leg, but felt no pain, a circumstance of which Wells was not slow to take notice. The following day, December 11, 1844, Mr. Colton, at the request of Wells, administered gas to him, and during the ensuing unconsciousness a Mr. Rigg, another dentist, extracted a molar from Wells' jaw. Wells, as he regained

* For an interesting account of Hickman, see *Brit. Med. Journ.* 1912, vol. i. p. 843. This article is contributed by the Wellcome Historical Medical Exhibition Research.

consciousness, cried out, "A new era in tooth pulling. It did not hurt me as much as the prick of a pin. It is the greatest discovery ever made."

After successfully employing gas as an anæsthetic among his own patients, Wells essayed a public demonstration in the operating theatre of the Boston General Hospital. The person experimented upon was not rendered completely unconscious, and gave unequivocal signs of having felt pain. This failure not only ruined Wells, who became insane, and finally died in prison by his own hand, having inhaled ether to ensure euthanasia in 1848, but it also discredited nitrous oxide as an anæsthetic.

With the death of Wells and the introduction of ether as an anæsthetic, the vogue of nitrous oxide, for the time, ceased ; but Colton, remembering his experience at Hartford, revived its use in 1863. Lee Rymer in England and Hermann in Germany undertook (1864-6) some experiments with nitrous oxide, and the important investigation of Krishaber followed in 1867.

Subsequently Colton induced various dentists to experiment, and in 1867 he was able to give a record of 20,000 successful cases. In 1868* the anæsthetic properties of nitrous oxide gas were successfully demonstrated at the Dental Hospital of London, and a committee of the leading English dentists was formed. The two reports published by these gentlemen, and read before the Odontological Society of Great Britain, spoke in warmest praise of the agent, and practically established its claims as a safe and efficient anæsthetic for short operations, in spite of considerable opposition on the part of certain members of the medical profession, who denounced nitrous oxide as unsatisfactory and dangerous.

The enthusiasm and ingenuity of Mr. Clover played no small part in obtaining the adoption of nitrous oxide for general use. It was shortly afterwards that Mr. Clover suggested what may be called one of the most important

* Colton, while in Paris, met with the well-known dentist, the late Dr. Evans, mainly owing to whose energy and munificence Colton's apparatus was conveyed to London, where the merits of nitrous oxide gas were brought before the English faculty.

improvements in practical anæsthetics, the employment of nitrous oxide as a preliminary to the inhalation of ether.*

The discovery of ether is attributed to an Arabian chemist, Djaber Yeber, and its methods of manufacture to Dr. Michael Morris, who also suggested that it could be used with advantage in medicine by inhalation.†

The general properties of ether, and its value as an inhalation, were well known before its use was suggested for the purpose of obtaining anæsthesia. In Pereira's work on "*Materia Medica and Therapeutics*," published in 1839, it is expressly stated that when ether is inhaled to produce a sedative effect in spasmodic diseases, there is a danger that the patient will become stupefied unless the ether vapour is sufficiently diluted. Its introduction as an anæsthetic, however, is commonly held to be due to American enterprise. It was fairly well known, and its properties recognised, as early as 1785, when Dr. Pearson, of Birmingham, employed it as an inhalation for asthma, and early in the last century it was used in the treatment of phthisis. In 1818, a paragraph appeared in the *Journal of Science and Arts*, which although unsigned is generally supposed to have emanated from the pen of Faraday; it runs: "When the vapour of ether is mixed with common air and inhaled, it produces effects very similar to those occasioned by nitrous oxide." Then follows an account of an experience with ether; a gentleman who inhaled became "lethargic," and so remained for thirty hours. Facts about the narcotic properties of ether were rapidly brought to light, and the writings of Orfila, Brodie, Giacomini, and Christison, all give more or less accurate accounts of the stupefying effects of ether. About the year 1840 it was a common trick at lectures and among medical students to inhale ether-vapour in order to induce exhilaration. A number of lads were indulging in this pastime in the outskirts of Anderson, South Carolina, and to stimulate

* See *Trans. Roy. Soc. Med.*, March, 1913, Section of Anæsthetics, and *Lancet*, March 29, 1913, in which an interesting leading article appears under the caption of "Joseph Clover, Surgeon and Anæsthetist."

† For much valuable information about the discovery of ether and chloroform, the reader is referred to Mr. George Foy's work "*Anæsthetics, Ancient and Modern*," pp. 23, 32, and 54. The author is indebted to Dr. Foy for various valuable additions made to this chapter.

further their mirth they seized upon a negro boy and forced him to inhale ether, pressing the vapour upon him until he became deeply narcotised and apparently dead. In an hour, however, to the delight of his tormentors, the negro resumed consciousness. This scene Wilhite asserted impressed itself so deeply upon him, that when three years subsequently he became the pupil of a Dr. Crawford Long, of Jefferson, Jackson County, U.S.A., he narrated to him, it is said, his experiences of ether.

Wilhite's claims were carefully examined by Marion Sims, who visited Dr. C. W. Long at Athens, and by Landon B. Edwards; they were convinced that Wilhite was not truthful; and Landon B. Edwards told Dr. Foy in 1894, at Dr. McGuire's house in Richmond, Va., that Wilhite afterwards confessed his falsehood and said he had concocted the whole story that his name might be associated with the great discovery. Wilhite was not in Dr. C. W. Long's employment at the time when Dr. C. W. Long etherised his first series of patients.

Dr. Long published in 1849 a statement that he had in 1842 administered ether to a patient, and while the patient was thus narcotised, a small tumour was painlessly removed. Dr. Long employed ether successfully in several cases, and the fact was well authenticated by his neighbours and by contemporary documents.* Long was a busy man as well as of a retiring nature, and he postponed publishing his cases until he was forced into doing so by the claims of monopoly advanced by Morton. Dr. Long appears to have acted in all candour and there can be no doubt that to him is due as a right the title of being the first man who actually employed ether in surgery and proved its value and its safety. Other medical men also about this time employed ether for surgical anæsthesia. It is stated that a student named William Clarke, in 1842, administered ether at Rochester, New York, to a patient for tooth extraction, and Dr. Marcy, also an American, operated upon an etherised patient in 1844.

However, the employment of ether as a general anæsthetic

* See *Trans. Roy. Soc. Med.*, vol. v. pt. i. p. 19, Section of Anæsthetics, in which a full account of the matter is given by the present writer, and facsimiles of the documents are given.

is more usually associated with the name of Morton, a dentist of Boston. William T. G. Morton was a pupil of Horace Wells, and from his master he gathered his first impressions concerning artificial anæsthesia. It would subserve no useful purpose to open up the miserable quarrels and recriminations which have been connected with Morton and his share in the introduction of ether as an anæsthetic. It will be best, therefore, merely to state the facts as far as possible without bias.

Wells made Morton his partner in a dental practice he proposed to start in Boston. The removal from Hartford to Boston was consequent upon a discovery Horace Wells had made of some solder with which he hoped to achieve great things. To confirm his own estimate of the value of this solder he called in a Dr. Jackson, a scientific chemist, who expressed a favourable opinion. However, the partners soon fell out, and Wells returned to Hartford, leaving Morton in Boston. The latter asked Wells for information as to the production of nitrous oxide, and was by him referred to Dr. Jackson. It was suggested by the chemist that trial should be made of sulphuric ether instead of laughing-gas, since it was more easily obtained. Acting upon the suggestion, Morton set to work with great assiduity to experiment, using chloric ether. He induced two students, Spear and Leavitt, to inhale ether, but the results were unsatisfactory. He next tried dogs, and used rectified ether, again at Jackson's instance, inhaling it from a tube attached to a flask. This is the story of Morton's discovery, given in his own words: "I procured the ether from Burnett's, and, taking the tube and flask, shut myself up in my room, seated in the operating chair and inhaling. I found the ether so strong that it partially suffocated me, but produced a decided effect. I then saturated my handkerchief, and inhaled from that. I looked at my watch, and soon lost consciousness. As I recovered I felt a numbness in my limbs, with a sensation like nightmare, and would have given the world for some one to come and arouse me. I thought for a moment I should die in that state, and that the world would only pity or ridicule my folly. At length I felt a slight tingling of the blood in the end of my third finger, and made an effort to touch it with my thumb, but without success. At a second effort I touched it, but

there seemed to be no sensation. I gradually raised my arm and pinched my thigh, but I could see that sensation was imperfect. I attempted to rise from my chair, but fell back. Gradually I regained power over my limbs and full consciousness. I immediately looked at my watch, and found that I had been insensible for between seven and eight minutes." A patient, Eben Frost, seeking to have a tooth taken out, and fearing the pain, requested Morton to mesmerise him, but Morton promptly seized the chance, and persuaded him that he knew a far better means of preventing the pain. The experiment was made, and on September 30, 1846, ether was successfully given by Morton and a tooth painlessly removed. The "discovery" was reported to Warren, the well-known surgeon, and by his consent a patient was etherised in the clinical room of the Massachusetts General Hospital.* The experiment was repeated, and each time proved a remarkable success. Warren, however, substituted chloric for sulphuric ether in subsequent operations, and is said to have preferred it.†

The possibility of narcotism by inhaling vapours having become an accomplished fact, it became necessary to find words expressing the agents used and the state induced. Morton adopted the term "Letheon,"‡ but this word soon fell into desuetude after the suggestion by Oliver Wendell Holmes of the expressions Anæsthesia for the state, and Anæsthetic Agent for the drug employed. Simpson regretted that the word Nodynia had not been accepted rather than Anæsthesia.

In England, the first administration of ether took place in Gower Street, London, close to University College Hospital, when Mr. Robinson, a dentist, gave ether and removed some

* The date of Dr. Warren's operation in which Morton first etherised a patient in the Massachusetts Hospital, Boston, as given by H. J. Bigelow in the *Boston Medical and Surgical Journal* of November 18, 1846, is October 16, 1846.

† "Personal Recollections of the First Use of Anæsthetics," by J. V. Galloupe, M.D., *Boston Medical and Surgical Gazette*, January 7, 1897.

‡ "Letheon" was the fancy name given for the drug which Drs. Jackson and Morton patented, hence it was not used by medical practitioners, and probably also because the smell of the anæsthetic revealed its identity.

Dr. King, of Boston, was one of the first to attack the validity of the patent, and in Great Britain and Ireland the most trenchant critic of the action of the "Letheon" patentees was the late Dr. Arthur Jacob, *Medical Press*, 1846.

teeth. This took place on Saturday, December 19, 1846, at the house of Dr. Boott. On Monday, December 21, Liston amputated through the thigh in University College Hospital, the patient being placed under the influence of ether by Mr. Squire.*

Dr. Snow, early in 1847, commenced the successful administration of ether in St. George's Hospital, but upon the introduction of chloroform he gave up ether for its more pleasant but possibly less safe rival.

On January 19, 1847, Dr. (afterwards Sir) James Young Simpson administered ether to a woman in childbirth, and subsequently adopted it in his obstetric practice. Notwithstanding the favourable experiences of many, ether was not rendered popular for some years subsequently. The methods in vogue for its administration were far from satisfactory; many patients never got beyond the stage of exhilaration and wild excitement, and their struggles and bacchanalian shouts were pronounced highly embarrassing to the operator. These considerations led Liston and other eminent surgeons to regard ether with suspicion, and made them diffident in invoking its aid. However, up to November, 1847, the time of Simpson's world-famous pamphlet, "Notice of a New Anæsthetic Agent as a Substitute for Sulphuric Ether in Surgery and Midwifery," ether was slowly but surely winning its way as a safe and trusty anæsthetic. With the introduction of chloroform, came the *coup de grâce* to the predominance of ether. With an almost incredible rapidity chloroform supplanted her elder sister, not only in Great Britain but almost throughout the world; in America, however, many surgeons still clung to ether. The story of the introduction of chloroform into Great Britain is soon told. Sir James Y. Simpson,† not wholly satisfied with ether in obstetric practice, asked Mr. Waldie, the Master of the Apothecaries' Hall of Liverpool, if he, as a practical phar-

* An extremely interesting and graphic account of this episode has been written by Dr. F. Cock, and published in the *Univ. Coll. Hosp. Gazette*, February, 1911.

† For an interesting account of Simpson's work in connexion with the introduction of chloroform, see "Sir James Y. Simpson" in *Famous Scots Series*. Also see Simpson's "Collected Works," vol. ii., "Anæsthesia."

macist, knew a substance likely to be of service in producing anæsthesia. Mr. Waldie became acquainted with the composition of "chloric ether," and suggested that its "active principle," chloroform, should be prepared from it and used. He never carried out his promise to prepare some for Simpson to try, and so the desired substance was obtained in Edinburgh, and Simpson, experimenting on himself, George Keith, and Matthews Duncan, on November 4, found its use perfectly satisfactory. He at once tried chloroform in his obstetric practice and met with success.

The favourable opinion he had formed he expressed in his paper before the Medico-Chirurgical Society of Edinburgh, November 10, 1847. On November 15, 1847, the first surgical operation was performed at Edinburgh, upon a patient who was under the influence of chloroform. It is curious to note how narrowly several persons escaped discovering the value of chloroform as an anæsthetic. Thus, chloric ether, a twelve per cent. solution of chloroform (by volume) in spirits of wine, was employed by Dr. Bigelow, of Boston, but with only partial success. Jacob Bell, of London, however, actually produced insensibility by its use as an inhalation, and Sir William Lawrence, the surgeon, employed it alike in private and hospital practice. Chloric ether was also used at St. Bartholomew's and the Middlesex Hospitals, but the great uncertainty of its action and the expense of procuring large supplies effectually prevented it from gaining ground as an anæsthetic.

Mr. George Foy has pointed out that in Silliman's *American Journal of Science and Art*, January, 1832, Professor Ives, of Newhaven, reports a case, in which chloroform was employed as an anæsthetic. Guthrie, an American chemist, was induced by a statement in Silliman's "Chemistry" that an alcoholic solution of chloric ether was a valuable stimulant, to attempt a cheap way of producing it.* Guthrie gives directions for the distillation of chloride of lime and "well-flavoured alcohol" of sp. gr. 0·844. Soubeiran's account of his discovery of chloroform, made apparently without any knowledge of Guthrie's work, appeared six months after

* See "The True History of the Discovery of Chloroform," by David Waldie, Edinburgh, Oliver and Boyd, 1870.

Guthrie's MS. was in the printer's hands. About the same time another independent observer, Liebig, published an account of chloroform, but he failed to recognise in his analysis the presence of hydrogen, and therefore regarded the material as a chloride of carbon. It was not until 1834 that Dumas, adopting more exact methods, revealed its true chemical composition.

Chloroform was experimentally studied by Flourens in 1847, but no practical uses were made of his work. For some while chloroform was believed to be a "safe anæsthetic," an impression to which the language of Simpson's pamphlet rather lent itself, although certainly no explicit statement to that effect can be found. Unhappily this belief received a rude shock on January 28, 1848, when a death from chloroform was reported at a place near Newcastle-on-Tyne. This untoward occurrence was soon followed by other deaths, and men's minds became anxious. At this pass Snow, with that earnestness and acumen which characterised all he undertook, commenced his researches into the subject. In 1848, he published his "Experimental Papers on Narcotic Vapours."

Although Snow had improved upon the methods in vogue for the exhibition of ether by the invention of his inhaler, he did not vaunt its merits above other narcotics, and in 1847 he perfected his chloroform inhaler, being actuated by the belief that that anæsthetic kills through being used in too concentrated a vapour. Snow's experience, like that of most others, made him regard chloroform as dangerous, and so in 1856 he was tempted to investigate amylene, of which substance he entertained a high opinion.

A committee appointed by the Royal Medico-Chirurgical Society of Great Britain to investigate the subject of anæsthesia tendered their report in 1864, and this report strongly insisted both upon the danger of chloroform and the inconvenience of ether as then administered. Many suggestions, such as the use of the A.C.E. mixture, were embodied in the report, some of which Clover, who had then achieved a high reputation as an anæsthetist, was not slow in carrying to a practical issue. In 1862 Clover had constructed and published an account of his chloroform apparatus by which he regulated the percentage of vapour administered.

Pollock and Warrington Haward in this country were keenly alive to the dangers of chloroform, and they lost no opportunity of urging the use of ether, an advocacy for which we must always feel grateful. As time went on, Clover was less and less inclined to use chloroform. For minor operations he found nitrous oxide gas given by his apparatus to answer best, and he was led to seek some means for prolonging anæsthesia so obtained. This he achieved by the employment of ether in succession to nitrous oxide, for which he soon devised an admirable apparatus, described in the *British Medical Journal* in 1876. It may be remarked that this inhaler is at the present time less known than its merits deserve. Subsequently his portable regulating ether inhaler was introduced, and it was mainly by the compactness and efficiency of this instrument that the practical question, how to give ether rapidly and safely, became answered. In latter years Clover adopted the use of "dichloride of ethidene," first introduced under the name "monochlorurretted chloride of ethyle" by Snow in 1851, but Clover's record of 1877 with one death did not lead to the general adoption of this new anæsthetic. In 1879, the British Medical Association undertook to reinvestigate the question of the relative safety of the various anæsthetics, and appointed a committee to carry out experiments. The conclusions to which this, the "Glasgow Committee," arrived were in favour of ether, as they found chloroform lowered the blood pressure and depressed the action of the heart. No record dealing with the earlier work done concerning anæsthetics would be complete without a reference to the valuable researches of the late Sir Benjamin Ward Richardson, the biographer of Snow. Many of his papers appeared in his journal *The Asclepiad*, and current periodicals. "Bichloride of methylene," a proprietary preparation at one time widely used, was one of Sir B. W. Richardson's contributions to general anæsthesia, as ether spray was one to local analgesia. In 1889, the Nizam of Hyderabad, at the suggestion of Surgeon Lieut.-Colonel Lawrie, granted a considerable sum of money to re-open the question, and the first Hyderabad Commission, working upon small mammals in India, came to conclusions more favourable to chloroform. As these investigations were not held con-

vincing by English experts, a second Hyderabad Commission, in which Sir Thomas (then Dr.) Lauder Brunton assisted, went over the ground again, and corroborated the results before obtained by the first Hyderabad Commission.

The *Lancet*, with public-spirited zeal, undertook and carried out an exhaustive report dealing with the clinical evidence on the uses of chloroform and other anæsthetics, and published it in 1893.* The results of clinical observations therein embodied did not bear out all the statements of the Hyderabad Commission. The British Medical Association, as a result of a discussion held at the Annual General Meeting at Bournemouth in 1891, when the present writer, at the request of the local secretary, Dr. C. Childs, read a paper on "The Clinical Aspects of Anæsthesia,"† appointed a Committee to study the question. The object of this paper was to point out that although there were many cases published of deaths under chloroform, yet no statistics existed showing the number of normal cases in which chloroform was used, so that it was a matter of guesswork to estimate a percentage rate of safety for that and other anæsthetics. The paper further demonstrated that careful records of cases which, although not terminating fatally, yet presented slight or grave dangers, must prove of value by elucidating how such dangers were caused and how they could be obviated.

The report of this committee appeared in 1900, and contained an analysis of 25,920 cases in which anæsthetics had been given and records kept.

The important researches of Gaskell, Hare, Leonard Hill, McWilliam, Shore, Waller, and Wood, have all appeared within the last few years, and have kept alive the controversy which has existed since the initial use of chloroform. These experimental results are considered more at length in the chapter dealing with chloroform.

It is not within the scope of this book to notice in detail the more recent work which has been sufficiently constructive to deserve a mention in the history of the subject. It may,

* This report was undertaken by the present writer, his work being facilitated by the encouragement given by the proprietors of the *Lancet*, and especially by that of the late Mr. Thomas Wakley, jun.

† *British Medical Journal*, vol. ii., p. 1090, 1891.

however, be noted that Dr. Embley, of Melbourne, by an important research, has increased our knowledge of the obscure subject of vagal inhibition during narcosis. This and other researches appear in the *Transactions of the Society of Anæsthetists*, a society which has done much to promote an intelligent study of anæsthetics. It now forms a section of the Royal Society of Medicine. The British Medical Association (1901) again testified its public-spirited interest by appointing a further committee* to investigate methods of quantitatively determining the presence of chloroform in the air and in the human body. The work of this committee has been published in an accessible form, the volume containing both the original papers and illustrations and the final report of the committee.

Perhaps the most remarkable advance made in anæsthetics during the last few years is the adoption of methods of introducing ether and other drugs directly into the bloodstream, and the intra-tracheal insufflation of ether directly into the lungs.

* The committee, as first appointed, consisted of Dr. (now Sir James) Barr, Dr. Dudley Buxton (Secretary), Mr. Vernon Harcourt, F.R.S., Sir Victor Horsley, F.R.S., Professor Sherrington, F.R.S., and Dr. A. D. Waller, F.R.S.

CHAPTER II.

PREPARATIONS FOR OPERATION: SELECTION OF THE ANÆSTHETIC AND METHOD.

GENERAL PRELIMINARIES.

Best time for taking an anæsthetic.—Although the anæsthetist seldom has the choice of time given to him, the selection of a suitable hour for the operation is not a matter of indifference in administering an anæsthetic. The effect of anæsthetisation upon the robust may be considered trifling and transient, yet when the person to be anæsthetised is an invalid, and either weakly or neurasthenic, the inhalation may have a dangerous and prolonged effect. Individuals are more liable to after-effects of an unpleasant character when their bodily condition is one of nervous exhaustion and lowered vitality. It is inadvisable, therefore, unless over-riding circumstances exist, to give an anæsthetic after an unduly prolonged fast. Similarly, it is unwise to select an advanced hour of the evening when the body will be spent after a day of activity or suffering. In the case of emergency operations, delay may be prejudicial, so that the above statements must be accepted as being applicable only to "arranged" operations.

Dietary.—Further, an anæsthetic should not be given within three hours of a meal of such food as is not easily digested, since a full stomach impedes the production of narcosis and excites vomiting. This last occurring during light narcosis may occasion fatal accidents through solids being drawn into the air passages. It is well to select the periods of greatest vital activity, and this is found in most persons in the morning (8 a.m.) or early afternoon (2 p.m.).

Speaking generally, it is well to arrange for a very slight meal of soft and easily digested matters to be taken three, or better four, hours at least before the surgeon arrives. But it is best when possible, unless the patient be in a very feeble state of health, to adopt Clover's rule, and give the last meal five or six hours before the operation. In the case of robust adults when the operation is to take place in the early morning, no food need be taken after the overnight dinner. This meal should consist of either broth, soup freed from fat, meat jellies, or easily digested foods, varying with the time of the day, and the choice of the patient. Milk, if taken by itself, is very apt to form curd in the stomach, which will be vomited in hard masses during the operation. This is especially liable to occur in the case of young children. Barley water added to the milk will often obviate the clotting. It is not wise to make the administration of stimulants before an anæsthetic a matter of routine. In every instance it is recommended that the bowels be cleared overnight with a laxative, and followed in the morning by an enema. A still better plan is, when the patient is under control for some days before the operation, for the bowels to be cleared out by medicine given on the second night *before* the anæsthetic is administered, followed by an enema on the morning of the operation. But some surgeons prefer, in the case of abdominal sections, to dispense with purgatives, and give copious enemata daily for a week before operation. Patients are spared much discomfort if they are dieted for a day or two before the operation. Only light nutritious foods should be given. The bowels should be carefully regulated. It often happens that a strong purgative, given the night before an anæsthetic is administered, upsets the digestion, and in bilious subjects increases the after-sickness. It is also as well to avoid, as far as possible, interference with the usual hour of the patient's meals, as food taken when the stomach is not accustomed to it, is liable to remain undigested and to cause vomiting. This is still more important in the case of the weakly and of those enfeebled by disease. A prolonged fast, or too free purgation, is very liable to produce syncope and other dangerous symptoms at the

time of the operation. In feeble subjects a nutrient enema of beef tea and brandy, or a nutrient suppository may be given half an hour previous to the operation. In all cases of great exhaustion or collapse before operation and when there is obviously poor resistive power, enemata containing glucose (3j) in saline should be given at four hours' interval for 48 hours before and after the anæsthetisation. Some surgeons recommend copious draughts of hot water in suitable cases of abdominal sections, given at intervals of four hours for three or four days before the operation, to prevent sickness and thirst. This is in all cases a better plan than giving alcohol by the mouth.

The following is a condensed form of a usual regimen to be adopted at the time of an operation other than in abdominal cases :—

Operation at 9 a.m.

No food unless the patient is greatly depressed ; if he is, a small cup of China tea with toast or Plasmon biscuit soaked in it, at 6 a.m. ; or a small basin of thin cornflour, or a tumbler of hot water containing glucose.

After the operation at 9 a.m., completed by 10 : if sickness occur, very hot water in which sodii bicarb. (3j to Oj) is dissolved may be given in sips from a feeder or porcelain spoon. As a rule, if actual vomiting has occurred a small glass of this alkaline drink gives the greatest relief and stops the sickness. At 2 p.m. essence of beef in jelly ; if much thirst, ice may be sucked, or iced soda and milk taken.

If very prostrate from vomiting, iced champagne or brandy and soda water.

At 6 p.m. a light meal of fish, unless the vomiting has persisted.

Operation at 2 p.m.

Breakfast at 7, tea or thin cocoa, bread and milk, fish, but no meat.

Clear soup or beef tea in small quantity (free from fat) if desired, at 11 a.m.

After the operation at 2, over at 3.

Bread and milk, or biscuit and tea or cocoa, at 7 p.m.

When nutrient enemata have been given for some days

preceding the operation it is well to let the patient sip hot water to allay the thirst, which otherwise may prove almost intolerable.

If only nitrous oxide is given, such preparation may be omitted. Even in this case it is well that an interval of some hours, preferably three or four, should intervene between the last meal and the administration. Fasting for several hours is best for patients who have to take nitrous oxide with oxygen, or ethyl chloride, even when for dental operations, as nausea and vomiting are not infrequent after these anæsthetics. In the case of children especially, it is well to see that they pass water before being anæsthetised, as micturition is often performed unconsciously whilst under the influence of gas.

Preparations for anæsthetic.—Assuming that the physical condition, as far as is necessary, has been examined, the patient about to be anæsthetised should be placed in the recumbent position, except in the case of dental operations under nitrous oxide. The clothing should be carefully loosened, corsets quite undone, neck bands left open, and waist belts removed and strings untied. It is important that the patient be as comfortably posed as circumstances will permit, for while tranquillity of mind and body go far to assist in the production of anæsthesia, anxiety and uneasiness will greatly retard its accomplishment. The patient should now be asked to open his mouth, and a glance given to ascertain if any artificial dentures or an obturator, etc., be worn. Such, if present, must be removed with as little annoyance to the patient as possible. It is wise to notice whether any loose teeth are in the mouth, as if it has to be opened with a gag the teeth may be disengaged and enter the air passages. Any obvious obstruction such as goitre, enlarged tongue, or if the tongue is bound down by adhesions, enlarged tonsils, hypertrophied uvula, nasal polypi, etc., should be noticed. A further step may be taken in reassuring the patient by a few cheery words, and, if necessary, directions as to how he is to take the anæsthetic. Such instructions are often of marked service by giving him something about which to think.

When, however, the anæsthetic is once well on the way,

quietness and silence must be maintained ; noise—notably in the case of nitrous oxide—militates considerably against easy and tranquil anæsthetisation.

Avoid conversation, especially about cases of patients who have died or suffered mishaps. A person going under an anæsthetic is apt to obtain a confused notion that the remarks apply to him, and he will grow nervous and excited.

Some conditions require special preparation of the patient. In operations for strangulated hernia, intestinal obstruction, and other cases, when there has been persistent vomiting, it is best, if the patient's state permits of it, that his stomach should be thoroughly cleansed, its contents being withdrawn by lavage and washing out with warm water. This precaution helps to obviate the fatal aspiration of vomit into the air passage during anæsthesia.

It is also well when the patient is weakly to wrap him warmly in flannel or cotton wool, as prolonged operation under an anæsthetic usually occasions a considerable fall of temperature and renders the patient more liable to shock, bronchitis, and pneumonia.

The room in which an anæsthetic is given should be well ventilated, but ought to be kept at a temperature of 65° or 70° F. It is undesirable to have gas burning in it, as when chloroform is being used that anæsthetic becomes decomposed, acid fumes of phosgene gas are generated, and these are not only very irritating to the eyes and throat but deleterious to the patient and to all in the room. It is always best that preparations for the operation be made out of sight and hearing of the patient. It may not be out of place here to insist upon the extreme importance on the part of the anæsthetist as regards **cleanliness**. All **apparatus** should be carefully cleansed before use, and the anæsthetist's **hands** and **nails** rendered absolutely clean. Not only is it unpleasant for the patient to see a discoloured hand near his face, but frequently the hands and apparatus of the anæsthetist cannot be kept out of contact with the area of operation and may be a source of **infection**.

Moving an anæsthetised patient.—It is never desirable to administer an anæsthetic to a patient on his bed, and subsequently carry him into the room in which the operation

is to be performed. It is apt to cause vomiting. I have also more than once seen alarming faintness occasioned by lifting the patient on to the table after he was carried from one room to the other. If, however, on account of the patient's extreme nervousness, or for other reasons, it is deemed best to anæsthetise him in an anteroom, the utmost care must be taken in carrying him into the operation room. Adults are best carried by four persons, each taking a corner of the sheet or blanket on which the patient is lying. When possible, the removal should be done by means of a trolley running on rubber tyres. If the patient is conveyed from one floor to another, his head should be kept lower than his body, provided this position is not inconsistent with the necessities of the patient or the nature of the operation. The same care should be taken in replacing him in bed after the completion of the operation. No patient should be left alone until he has fully regained consciousness, as the state of returning volition has special perils. The dangers to be looked for and guarded against are (1) the head may be rolled into a faulty position and respiration become impeded, (2) the patient may become asphyxiated by vomiting when his head is not turned to the side, (3) the patient may suddenly sit up as in the act of vomiting and faint.

Vomit is often very irritating, especially if bilious. I know of cases in which the fluid was allowed to go into the eye, causing conjunctivitis and pain for some hours subsequently. Possibly the vapour of chloroform which is condensed in the mouth and swallowed may account for the deleterious character of the vomit. To obviate this risk as well as to safeguard against the irritation caused by the anæsthetic vapour a few drops of pure castor oil may be dropped into the eyes as soon as the patient is unconscious and a pad of lint then placed over them.

When alkaloids (see p. 36) are to be employed the injection should be made one hour or one hour and a half before the anæsthetic is given. After this the patient must be kept absolutely quiet, and no talking or movement should be allowed in his room, nor must he be allowed to walk to the operating room, as such a proceeding will certainly occasion giddiness or even faintness.

The choice* of an anæsthetic must depend on

1. The condition of the patient.
2. The necessities of the operation.

1. CONDITION OF PATIENT.

The choice of an anæsthetic in any case can only be satisfactorily made after a careful examination of the patient, and the nature and probable severity of the operation to be performed have been ascertained.

Besides the actual malady for which operation is proposed, it must be ascertained whether intercurrent pathological conditions are present.

Examination of the patient.—The physician who is in charge of the patient can usually give all requisite information about his general condition, but it is desirable that the anæsthetist should have the opportunity of making a personal examination.† When possible this should be done the day before the operation, as it is better not to expose or fuss the patient just before he submits to the anæsthetic. The examination should be conducted as quietly and reassuringly as possible.

GENERAL APPEARANCE, POSTURE.

Much can be learnt by inspection. The colour of the skin ; whether the lips and ears are bluish or anæmic ; pitting of the skin ; pallor or plethoric redness are all important signs. Alertness, or sluggishness or feebleness in movement betokens vigour or the reverse. The posture naturally assumed must be noticed, as if it indicates the presence of dyspnœa or orthopnœa, it is also the position which is most favourable for the patient when under the anæsthetic. This is of great importance in cases of goitre and other neck swellings, of thoracic disease, empyema, and kindred troubles—also in cases of abdominal distension, especially when the patient is obese—and the

* The question with whom lies the choice of the anæsthetic is considered in detail in Chapter XII.

† See discussion on the desirability of the anæsthetist examining the patient, *British Medical Journal*, 1912, vol. ii., p. 612. A strong consensus of opinion favoured the view given above.

utmost care should be taken to retain the patient in this posture so far as the exigencies of the operation may permit. If a change of position has to be made it must be done slowly, and the effect of it carefully noted. At the close of an operation undue and rough lifting of the head and trunk often causes faintness and commonly starts vomiting ; this is frequently noticed after severe operations on the breast. The eyes should be looked at, and dilatation or contraction of the pupils with the ocular movements noticed. It should be ascertained whether belladonna, opium, or other drugs have been taken recently. The presence of habits of excessive indulgence in alcohol or tobacco may with advantage be investigated, as the former tends to produce delay and excitement during the induction of anæsthesia, and the latter not infrequently induces pharyngeal catarrh and intolerance towards ether.

A fixed rigid chest with straight shoulders, as a rule, means a dangerous and difficult narcosis, even if no actual bronchitis is present. The plethoric and short-necked, and the unduly fat with protruding abdomen, are always short winded and subject to respiratory difficulties under the anæsthetic, being very prone to spasm affecting the respiratory tract. I am sure that too doctrinaire an adhesion to the rule that the head and neck must be kept low during induction is a mistake in these, and indeed in many other cases. Provided the head is not flexed on the trunk, short-necked and stout persons breathe best when their head and shoulders are on an inclined plane and higher than their abdomen. After induction they can, if necessary, be lowered, and certainly should be so placed if the operation is upon the abdomen or involves much hæmorrhage. This matter is referred to in a later chapter.

Too much importance should not be attached to the pulse rate. It may run up to 100 or more in nervous people. Of course a pulse rate above 100 associated with proptosis suggests the serious condition of true tachycardia and calls for most careful examination, and seeks for corroborative evidence. The regularity in force and rhythm and compressibility are of greater moment, and will give a clue to the condition of the circulation and to the patient's resistive

power against shock. Intermittence of the pulse is often congenital and unimportant, and can, if present, usually be explained by the family attendant. In every case the urine, both as regards quantity and the presence of pathological constituents, must be examined. If the chest and abdomen can be studied, the main points to be observed are : firstly, the general conformation of the chest and its movements ; the presence of pulsation and the area of cardiac impulse and dulness ; the characters of breath and heart sounds, and if murmurs exist, their character—whether hæmic or not—and the direction of their conduction. The evidence of valvular disease is of less importance than whether the lesion revealed is compensated or the reverse. If the impulse is feeble and the heart sounds distant, it is well to ascertain, as far as can be done, whether there are further signs of a fatty and feeble heart muscle. Such a condition is of very much greater import than mere intra-cardiac valvular disease unassociated with consequent pathological changes.

Displacement of the heart from whatever cause should be most carefully noted, both, because the condition may arise from intra-thoracic causes which are probably detrimental to the respiratory or circulatory functions, or from pressure from the abdomen, a condition possessing its own dangers in the direction of inducing syncope, and because it may evidence cardiac dilatation and hypertrophy with probable disabilities. In all cases of obvious frailness or feebleness the height of blood-pressure should be carefully noted, and further and useful help should be obtained by the use of Dr. Oliver's arteriometer.* The value of noting blood pressure was advanced by the author in cases of shock, and wider experience has convinced him of it.† It is also wise in cases of grave anxiety to examine the blood, making not only a blood-count, but an estimation of the hæmoglobin. Inspection of the neck must also be carefully made to determine whether there is any swelling or undue shortness and fulness, and if the veins are normal, dilated, or incompetent. Goitre, enlarged glands,

* See "Studies in Blood Pressure, Physiological and Clinical," 2nd edition, by Dr. G. Oliver, for further information upon this point ; also "Observations on Blood Pressure," by Dr. Rudolph, Canadian Institute *Transactions*, vol. vii.

† *Trans. Roy. Soc. Med.*, 1909, vol. ii. pt. I. p. 55.

and inflamed areas in this region, will often cause respiratory difficulty, and unless a judicious choice of the anæsthetic be made will possibly lead to disaster.

The general inspection having been made, we may consider the condition of the patient more in detail.

The upper air passages and thorax should be examined for any cause of **dyspnœa**. This may arise from *nasal obstruction, morbid growths* blocking the nasopharynx, *vegetations, polypi*, etc.; from *hypertrophied tonsils or uvula*; *morbid growths* or *œdema* of the *palate, fauces, tongue, gums*, or posterior *pharyngeal wall* (e.g. spinal abscess) or *larynx*. In stenosis narium, and especially when associated with valve-like insucking of the muscular lips of the edentulous, inspiration becomes greatly hampered. Goitrous growths and swellings, whether glandular or not, are liable to interfere with breathing, the dyspnœa as a rule increasing as the patient passes under the anæsthetic. When postnasal adenoid growths and hypertrophied tonsils are found associated with enlarged cervical glands the possibility of the condition called lymphatism must be borne in mind. Search would then be made for general glandular enlargement, the presence of an enlarged thyroid gland, and a persistent thymus. It is stated that this last can sometimes be detected either by percussion or by its casting a shadow upon the screen under X-rays. The other symptoms need not be adverted to in this place.* Epistaxis may prove a troublesome complication, and any tendency to it should be borne in mind.†

Tumours in the neck or thorax may, by pressure upon the trachea or bronchi, cause dyspnœa, e.g., aneurism, lymphadenoma. Laryngeal œdema, obstruction, or paresis should be looked for.

Diseased conditions of the *nervous system* may cause interference with respiration through pressure upon the spinal cord

* See *Trans. Soc. of Anæsthetists*, vol. iii. p. 41, in which Dr. McCardie discusses lymphatism; and a clinical lecture by the author in the *Lancet*, August 6, 1910, in which is reviewed the present knowledge of this curious condition.

† The possibility of foreign bodies passing from the alimentary tract into the upper air passages should be remembered. Besides regurgitation of fluids, etc., from the stomach, I have met with a case in which round worms were passed up in this way and caused respiratory obstruction.

or pons, and upon the roots of the nerves associated in the act of breathing. Thus I have on several occasions given chloroform to patients whose respiration was solely diaphragmatic or greatly affected through injury to or disease of the spinal cord, or by cerebellar and bulbar tumours. Conditions such as these would induce the anæsthetist to minimise the quantity of chloroform given, as ordinary doses would prove fatal.

Pulmonary and pleural diseases are referred to more in detail below. Dyspnœa, accompanied or not with fever, cough, expectoration, hæmorrhage, fixation of the chest, or unequal and impaired movements indicate the avoidance of any anæsthetic or method of giving it which might increase the respiratory embarrassment. Ether, if forced and associated with increased secretion of the mucous and other glands or with cyanosis, would, for example, almost asphyxiate in such conditions, but chloroform slowly given in a high dilution would be well borne and might in suitable cases be followed by ether from a regulating inhaler.

The colour of the patient is a material point in these conditions as well as when the heart is working at a disadvantage. *Cyanosis*, from whatever cause, increases the risk of the anæsthetic, and every means should be adopted to obviate it. I have found oxygen serves most usefully both as an adjunct to ether and to chloroform in dealing with such conditions, and in cases of marked cyanosis I have succeeded beyond expectation by combining its use with that of the anæsthetic.

Besides cyanosis other symptoms, such as the character of the *arterial pulse*, the *impulse* and *apex beat* in the cardiac area, *pallor*, *venous* or *capillary congestion*, the presence of *varicose veins*, *aneurism*, *œdema of the ankles and feet*, should be noted, so that the state of the circulation may be known. The quantity and character of the *urine* must be considered. Both ether and chloroform may increase albuminuria, and ether when given in large quantities and for a long time is liable to set up mild nephritis. Whether ether acts as the determining agent or only as a factor in causing suppression of urine after severe operation shock is a moot point. Certainly it is advisable to limit the quantity of anæsthetic given if the kidneys are in any way morbidly affected.

The abdominal viscera.—In cases of "stoppage of the bowels," and of intractable vomiting from whatever cause, the anæsthetist requires to be thoroughly acquainted with the condition and to be upon the alert to obviate the dangers incident to the vomiting.

When extreme *thoracic or abdominal distension* exists, due to gaseous or fluid accumulations such as pleuritic effusion, empyema, distension of the intestines, ovarian, renal and other tumours, dropsy, or peritonitis with much effusion, there may be considerable interference not only with respiration but with circulation owing to cardiac displacement. The anæsthetic will in these cases cause increase in the dyspnœa and tendency to syncope unless the greatest care is taken. The suitable arrangement of the position of the patient's body so as to give him the easiest posture for breathing, and the very gradual administration of the anæsthetic will help to combat these dangers.

CHOICE OF ANÆSTHETIC.

ROUTINE IN HEALTHY SUBJECTS.

For all *brief operations*, both in dentistry and general surgery, NITROUS OXIDE GAS may be advantageously given. It can be administered to infants and elderly people as well as to adults. In all conditions in which any respiratory difficulty exists, in cyanosis and in asthenic states, it is well to give it combined with oxygen, but when that method cannot be pursued, nitrous oxide with air (see p. 80) gives, in skilled hands, almost as good a result, although at present the methods of administering it are less precise. As an alternative to nitrous oxide, ethyl chloride is useful for short operations. Sickness is more likely to occur after its use than after gas when administered by itself; the choice between the two agents must depend upon whether the risk of vomiting is deemed an insuperable drawback. According to some authorities, ethyl chloride given by an open method is less subject to this criticism (Chap. VI.). With ethyl chloride, a longer and somewhat more profound narcosis is obtainable.

Sex and age.—Difference of sex is really simply that of physique and musculature and must be considered under those heads. Ether, either in succession to nitrous oxide according to Clover's method, or following ethyl chloride, or given by itself, is the best and safest anæsthetic for general purposes alike for adults and children, and should be adopted as the routine method of producing unconsciousness before operations. There are, however, conditions which are often held as justifying a deviation from this routine, and these are noticed below. It may be pointed out, however, that, although apparently a long list, these conditions really represent a very small minority of cases when compared with the great number of instances in which ether should be adopted unhesitatingly. Ether given by means of a closed inhaler and in succession to nitrous oxide is the most rapidly acting anæsthetic, but when the length of induction is immaterial, ether may be given by an open or semi-open system (pp. 160 and 155), which obviates some of the drawbacks commonly advanced against the closed method. As a rapid induction is desirable for nervous people, and most persons are nervous about anæsthetics, it is an excellent plan to induce anæsthesia by the gas and ether sequence, using an inhaler, and to maintain anæsthesia by a semi-open system (p. 155). Whenever ether is to be used, a preliminary hypodermic injection of atropine (gr. $\frac{1}{100}$ or gr. $\frac{1}{150}$) should be given, provided no contra-indication is present. When this plan is adopted most of the objections formerly advanced against the use of ether disappear.

Childhood.—Infants and young children bear chloroform well, and resent having their mouth and nose covered by a face-piece, an objection, although by no means an insuperable one, to the use of ether. In many instances also ether produces much bronchial irritation in children, so that the best anæsthetics in these cases are the A.C. mixture,* or one of chloroform and ether. Ether may be given to children in the following way. The ether is dropped upon a Schimmelbusch's or Skinner's mask covered with several layers of gauze between two of lint, and held over the face. I have for

* A.C. mixture, one part by volume of Alcohol and nine of Chloroform.

years used this plan in dealing with feeble anæmic wasted children with success and satisfaction. I have, however, found that in most cases if you can win the child's confidence he will take nitrous oxide well, and ether can then be given in succession. Patience rather than force will usually succeed. It is important to give ether lightly, as children readily yield to its influence and require little to maintain anæsthesia. When they will not tolerate nitrous oxide, or ethyl chloride, a little A.C. mixture or chloroform dropped on a handkerchief, when a mask cannot be used, will serve to quiet them and as soon as consciousness is lost ether can be substituted. A few drops of eau de Cologne put on the mask disguises the unpleasant smell of ether or chloroform, and is regarded by the child as "a treat." In very prolonged operations the greatest care must be taken that children are not drenched with ether; it is unnecessary and is liable to cause baneful after effects. I usually give chloroform from a regulating inhaler in the later stages of a long trying operation on children, even when they are rendered anæsthetic with gas and ether or ether. This is to avoid the cooling which ether produces and which is especially deleterious in the case of the young.*

Children of about five or six years of age may be given gas and ether, unless they are notably the subjects of respiratory trouble. They will probably strongly rebel against having the face-piece applied, so that if it be desirable to avoid "a scene," the mixtures of chloroform and alcohol may be substituted and given by the open method. Although the use of chloroform is unquestionably attended with happy results in the case of children, it must be remembered that deaths from this agent are by no means confined to adults. The peculiar liability of children to fatal syncope under chloroform if they suffer from lymphatism and toxæmic changes consecutive to chloroform (delayed chloroform poisoning—Acidosis) must be carefully considered in this connexion. It cannot, therefore, be too strongly impressed upon the mind that children run a risk, and

* See a paper by the present writer in Report of the Special Chloroform Committee (British Medical Association), p. 51, dealing with anæsthetisation of children with chloroform by the Vernon Harcourt Chloroform Regulator.

probably as great a risk, in chloroform narcosis as do adults. Children take ethyl chloride well, although they are often alarmed by the tightly fitting mask usual for its administration so that it is probably better to use this anæsthetic by an open method (*vide infra*, Chapter VI.).

For the **aged**, that is for those over 60 years of age, chloroform is commonly held to be preferable to ether and in many instances such is the case. It is, however, true only because persons past middle life are often the subjects of chronic bronchial troubles, their arteries and kidneys are also frequently diseased and so may be injuriously affected by ether. Old persons too, like infants, are peculiarly susceptible to a bronchial and laryngeal irritability inducing distressing cough, dyspnœa and exhaustion. However, for aged and feeble subjects with weak hearts and depressed vitality, ether, notwithstanding the above-mentioned drawbacks, is beyond doubt the best anæsthetic; especially is this true when atropine has been given as a preliminary, and an open or semi-open method of giving the ether is adopted. It often happens that when cough is at first excited by ether the administration of a few inhalations of chloroform will remove all dyspnœa and allow the subsequent employment of ether. In a certain number of cases ether proves an impossible anæsthetic for the old, however carefully it may be administered, and such cases must be recognised and dealt with on their own merits, chloroform being substituted. Although advanced age in itself does not contra-indicate the use of nitrous oxide gas before ether, in some cases, *e.g.*, tendency to high vascular tension with feebleness of circulation, ethyl chloride or a little A.C. mixture may be employed in its stead as an antecedent anæsthetic to ether.

In **middle age**, when the patient is vigorous and muscular, ether preceded by nitrous oxide gas, or ethyl chloride should be employed, as this prevents struggling, and rapidly and pleasantly produces anæsthesia, and this is true even if chloroform or "open ether" is adopted as soon as induction has been completed.

Pregnant women take all forms of anæsthetics well, but if excitable and nervous, as they are apt to be, it is better

to avoid the coughing and straining which may follow the employment of ether. It will be found that unless very nervous, women in this condition take nitrous oxide followed by ether well; as little of the anæsthetic should be given as is consistent with true anæsthesia, as it is manifestly important to avoid vomiting. An anæsthetic should not be given to a woman over eight months pregnant unless the operation is imperative. If, however, the surgeon must operate, there is no valid reason why the anæsthetic should not be given. I have administered to ladies in the ninth month of pregnancy without untoward results. When women are very prone to abort, it is well, if possible, to defer both the operation and giving an anæsthetic during pregnancy. Whether the nervousness and general upset are not as much factors in producing abortion in such cases as the anæsthetic may be questioned.

ALKALOIDS GIVEN WITH GENERAL ANÆSTHETICS.

Although the question of the employment of alkaloidal bodies in connexion with general anæsthetics will be considered in detail later on (Chapter VII.), rules may be given here guiding the administration in their use. Division of opinion exists as to which combination of such drugs should be employed, or whether one only is indicated. The ordinary contra-indications to the alkaloids obtain as a matter of course, and should such exist, the preliminary use of the substances likely to be deleterious would be omitted.

Atropine salts given in gr. $\frac{1}{100}$ to gr. $\frac{1}{100}$ dose for adults is now practically always employed before ether, but as some persons suffer from the throat dryness, the dose may be lessened if preceding experience has shown a marked action of the drug in this direction. My experience goes to indicate that gr. $\frac{1}{100}$ is usually necessary to prevent salivation and flooding of the bronchi with fluid. The best effects are produced with the following combination: Atropine gr. $\frac{1}{100}$, morphine gr. $\frac{1}{8}$, scopolamine gr. $\frac{1}{100}$, given hypodermically one hour or one hour and a half before the inhalation is

commenced. These drugs appear to antagonise in some ways and to act concurrently in others. I think there is less of a morphine effect when scopolamine is added, although of course the latter exerts its own specific effect. The doses given above must be modified to suit the age, physique, and general condition of the patient.

During recovery the patient needs watching, as the post-operation sleep is often prolonged and deeper when alkaloids are used. It is asserted that omnopon replacing the morphine is safer. Absolute quiet should be enforced after the injection, and the patient should not be allowed to sit up or walk to the operation room.

CHOICE OF ANÆSTHETIC IN DISEASE.

The imbecile, lunatics or persons in delirium can be given anæsthetics and take gas and ether easily. It is well known that any disturbance of the cerebral circulation is liable to superinduce attacks of mania in persons who have once been maniacal, and so taking chloroform or ether may produce such an attack. Such attacks do not always or even frequently occur after anæsthetisation, as far as my experience goes, and I have notes of very numerous cases of anæsthetics given to the insane which support this statement.

Alcoholism.—Persons addicted to alcoholic excesses take anæsthetics badly. They usually show excessive restlessness, become much excited, and require a large amount of the anæsthetic to render them unconscious. Such persons are best given nitrous oxide followed by ether, but they often become greatly cyanosed, and to relieve this condition chloroform must be given for a time, even if ether be subsequently resumed. As a rule, oxygen given with ether prevents this cyanosis, unless the blueness is due to severe spasm. I have found that some confirmed alcoholics remain restless and rigid even during profound narcosis. When there is no contra-indication to their employment, the use of morphine and atropine with or without scopolamine by hypodermic injection before giving the general anæsthetic will produce a better and more tranquil anæsthesia than can be hoped for without their employment.

Respiratory tract.—*Larynx, trachea, bronchi, lungs and pleural cavity.* Intra-laryngeal disease demands chloroform, and the same may be said of severe affections of the trachea and bronchi, especially when the affection is acute and the dyspnœa urgent. In *diphtheria*, chloroform alone or combined with alcohol usually gives a satisfactory result. When the asthenia is very severe it is safest to use a Schimmelbusch's mask and drop the chloroform mixture upon it. Ether may be used from time to time to assist the circulation, without impeding respiration. In *bronchitis* and *lung disease*, when much *cough* and *dyspnœa* exist, ether is seldom well tolerated. If used at all it must be given from a semi-open inhaler, such as an Allis, or dropped upon a gauze-covered frame, with a preliminary injection of atropine. In these cases, if the patient cannot bear some mixture of ether with chloroform, such as the A.C.E., it is best to obtain anæsthesia by means of chloroform or the A.C. mixture. Ether or a mixture may be tried when anæsthesia is established, but if ill-borne, chloroform must again be employed. As a rule, chloroform, especially when given in the A.C. mixture, from first to last is the best and safest anæsthetic when the lungs are the seat of acute or active disease. In *pneumonia* or *œdema of the lungs* ether should not be given under any circumstances, as it tends to embarrass the lungs still further. Chloroform may, however, be used, but must be largely diluted with air, or still better with oxygen and given by a regulating inhaler. *Phthisical persons*, when the coexistent bronchitis is not severe, and cough and expectoration are not prominent symptoms, will, as a rule, take nitrous oxide and ether without discomfort or detriment. When, however, ether excites cough and causes distress, chloroform must be substituted. *Bronchitis*, if associated with *emphysema*, often causes extreme intolerance of ether, but the A.C., the A.C.E. mixture, or failing these, chloroform, will usually suit this condition. When *emphysema* is the most pronounced symptom, a difficult problem is presented. There is in most instances a dilated and weakly heart associated with it, and any anæsthetic may lead to dangerous consequences. Ether will in a few cases set up severe cough, spasm, and almost asphyxiate the patient.

On the other hand, if chloroform is used, there is always a danger, unless extreme care is taken, that an overdose may be given, owing to the failure of expiratory power in the lungs and the fixation of the thorax. The dyspnœa, spasm, and cyanosis set up by the ether will often disappear at once when the ether is replaced by chloroform. Ether, when given after atropine and by an "open" method and associated with oxygen, appears to produce less dyspnœa and spasm, and if ether is employed this method should be given a trial. The adoption of the A.C. mixture in the later stages of the case, and care that the chloroform vapour be given very dilute, will usually bring the administration to a successful conclusion. It is in such cases that the chloroform apparatus of Mr. Harcourt affords the most valuable aid, as it enables the administrator to limit with exactitude the percentage of vapour at any stage of the narcosis, but oxygen should always be given *pari passu* with the chloroform.

Asthmatics as a rule take the A.C. mixture or chloroform better than nitrous oxide or ether, but when the initial stage of anæsthesia is passed, if but little bronchial secretion is present, ether will be well borne.* *Asthmatics* are usually relieved by nitrous oxide and oxygen, but while some patients have assured me that this combination causes a painful sensation of impending suffocation, others have asked whether it could not be given to them when their paroxysms occur, as it relieved their respiratory distress in a marked degree.

If fluid is present in the pleural cavity as in *pleurisy with effusion* or *empyema*, especially when the heart is mechanically much displaced, anæsthetics are badly borne. This arises more from the posture which the operation necessitates—commonly one which the patient if conscious would be unable to assume owing to cough, dyspnœa, and failure of the heart's action—than from any inherent action of the anæsthetic. In cases of pleuritic effusion, and when an empyema does not communicate with the lung, if the patient can tolerate ether there is no reason why he should not take it while the initial and only painful part of the operation is performed. Usually,

* It has been pointed out by Mr. Tyrrell (*Transactions of Society of Anæsthetists*, March, 1898), that in many persons ether relieves asthmatic seizures, an observation which bears out the experience of M. Lépine, of Lyons.

however, too much cough and spasm follow the use of this anæsthetic in these cases, so that the A.C. mixture or some other dilution of chloroform has to be employed. In my own practice I am in the habit of employing chloroform for most cases of lung and pleuritic disease, and have convinced myself that, upon the whole, this anæsthetic is the safest. It is best to use warmed oxygen for such patients. The use of nitrous oxide and oxygen for operations for empyema has not any advantage over chloroform, and frequently causes very grave dyspnœa and cyanosis. In any case the lighter the narcosis is, the better are the chances of the patient.

It is often requisite to decide what anæsthetic will be best for persons subject to *oft repeated attacks of bronchitis and bronchial catarrh*, even though they may be quite well at the time of the operation. If in such cases the attacks are easily excited and liable to endanger the patient's chances of recovery, ether will be best replaced by a mixture or by pure chloroform. I think that when some inhaler, such as Mr. Harcourt's, is used, so that the dose of chloroform can be kept strictly at or below two per cent., there is no doubt that, for all persons whose lungs are affected, chloroform is the best anæsthetic. When, however, chloroform is given in higher percentage it is often dangerous and should be avoided. Of course the general state of the patient must be taken into account, and the possible arguments against the use of chloroform receive due consideration.*

I have found from the experience of the past few years that ether can be often taken well and borne without bad after effects, in cases of lung and pleural disease, when it is administered well diluted with oxygen, and when atropine has been previously injected, and preferably when it is employed by an open method, and provided the operation is not a prolonged one such as would necessitate the inhalation of a large quantity of the anæsthetic. Much of the cough, cyanosis, and distressing struggling which usually accompany the attempt to administer ether to persons suffering from dyspnœa, is caused by spasm set up by the ether. This spasm is at once relieved when the ether is given with oxygen, the patient

* M. Lépine has shown that if the ether is pure, and it is given with care, bronchitis is not increased by its use.

rapidly passing into profound narcosis without further trouble. The oxygen further stimulates the circulation, steadying and improving the action of the heart.

I have in some very bad cases of pulmonary embarrassment employed rectal etherisation with success.

Diseases of the circulatory system.—Although the existence of heart disease and vascular irregularity should materially influence the choice of the method in which an anæsthetic should be given, it very seldom vetoes the use of general anæsthesia. As Snow said—"If a patient is able to undergo an operation, he will not be an impossible subject for an anæsthetic."

In **mitral disease** when the pulmonary circulation is interfered with, and some cyanosis and possibly slight œdema with cough and dyspnœa exist, ether usually increases the distress. The employment of chloroform preferably diluted as in the A.C., the A.C.E., or Billroth's mixture, exhibited from a mask and by a drop method frequently steadies the heart. It is well to give such patients a course of digitalis before the operation, or a hypodermic of digitalin or strychnine preferably with atropine half an hour previous to the anæsthetic. The mere presence of a mitral murmur, without symptoms or failure of compensation, need not deter from the use of nitrous oxide and ether. Some authorities prefer to commence with the A.C.E. or C.E. mixture, and in such cases, if it can be borne, to give ether as soon as anæsthesia is established. I have found oxygen a valuable adjunct to the ether in all cases when cyanosis existed and when the presence of œdema of the lungs did not contra-indicate the use of ether. The state of the pulse should always be noted before an anæsthetic is given, both as a guide to the condition of the patient's circulation and also for comparison in the subsequent stages of the anæsthesia. The various causes of pulse variation must in this connexion be remembered,* and the share which respiration, cardiac action, alteration in capillary resistance and renal adequacy, and various cerebral conditions, take in affecting the rhythm, force, and frequency of the pulse, should be duly

* See "The Pulse," by Sir William Broadbent, Bart., M.D., F.R.C.P. ; and "Pulse Gauging," by G. Oliver, M.D., F.R.C.P., may be consulted with advantage in this connexion.

appreciated. It is wise also to estimate the blood pressure of these patients. It must be remembered that in all cases of pulmonary disease, whether primary or following mitral disease, there may always be a danger when ether is given for any length of time, lest waterlogging of the lungs or œdema should arise as a later and dangerous sequela of that anæsthetic. The preliminary injection of atropine, gr. $\frac{1}{100}$, probably lessens this danger, but it does not remove it. It is, therefore, my custom, even when I commence the inhalation with nitrous oxide and ether, to change to chloroform if the operation occupies any period of time exceeding half an hour.

In **aortic disease** there is a special danger from struggling, and a liability to syncope. I have found that persons so affected take nitrous oxide and ether well, but care should always be exercised to avoid any undue straining or struggling. The merit of nitrous oxide gas, preferably with oxygen, given before ether lies in the fact that struggling is avoided. The advisability of the preliminary use of morphine, scopolamine and atropine must be discussed. This method lessens the danger of struggling, and, provided a suitable dose is chosen, does not interfere with the heart, while it probably protects against reflex vagal inhibition. These subjects also, as a rule, take chloroform well, and this, or a mixture of it, can be given instead of gas, while ether can be employed in the later stages. Such patients, it must be remembered, are peculiarly liable to syncope as they are resuming consciousness, and the most sedulous care should be taken to prevent them from sitting up, either during the administration, or until the effects of the anæsthetic have quite disappeared. As they pass from under the influence of the anæsthetic they retch or vomit, and these acts are often accompanied by an alarming fall of blood pressure. In all forms of heart disease it is safer to administer slowly and warily, and to maintain a fuller dilution with air or oxygen than is at all necessary in ordinary cases.

Degenerations of the myocardium.—When the heart muscle has undergone structural changes, the danger of producing anæsthesia is greatly increased. It should be remembered that in severe degrees of anæmia there is evidence that the muscle cells of the heart present the

appearance of degeneration and lose the natural resiliency. Any alteration in the respiratory or vascular systems induced by anæsthetics imposes an extra strain upon the already weakened and diseased heart—one which it may be unable to sustain; hence supervenes syncope. There seems also a danger, as Dr. Leonard Guthrie has pointed out, that chloroform may itself, as indeed is the case with other anæsthetics, induce a degeneration in the heart muscle in children, a grave condition when superadded to initial disease. When the heart trouble is not complicated by pulmonary engorgement, œdema or hydrothorax—when it is in short largely compensated—ether should be given. I am in the habit of using oxygen with ether in these cases, and find it materially assists the patient, and, I think, lessens the danger. Although it is often suggested that an open method is safer, I am not convinced that this is so, since with a Clover's inhaler you can, by frequently removing the mask or refilling the inhaler bag with oxygen, give any degree of dilution of ether you require. This desideratum can, however, be obtained when a rigidly drop method of giving ether with a gauze-covered mask is adopted, and, given skill and experience, I regard this plan as excellent. The real danger lies in allowing the patient to inhale large quantities of ether, and "open" ether methods in the hands of those who lack experience lend themselves to this form of dangerous administration. When pronounced pulmonary trouble exists and ether cannot be borne, chloroform or the A.C. mixture may be given.

Should nitrous oxide be administered in cases of MORBUS CORDIS? I have records of practically every form of heart disease in patients to whom I have repeatedly given anæsthetics, but when no pulmonary disease coexisted, nitrous oxide has caused no alarming symptoms. The complication of cyanosis and lung trouble with a dilated weak heart is a grave one. Sometimes nitrous oxide with oxygen is well taken, even by persons so afflicted, but there is no small risk, and the greatest care and experience are needed to bring the case to a satisfactory issue. If the case is one of advanced disease and the heart is working feebly, it is wise to supplement the nitrous oxide by allowing it to mix with ether

vapour. This plan has in my hands answered most admirably. Although I cannot at present claim a wide experience of the plan, I consider that warming the nitrous oxide and oxygen before inhalation materially lessens their deleterious effects and appears to enhance their action.

Chloroform, whether pure or diluted, cannot be given to persons having diseased hearts without increasing the risk of syncope, due to the unavoidable fall in blood pressure which follows the use of this anæsthetic. This fall, however, can be minimised by using only low percentages of chloroform vapour. On the other hand, it must be remembered that in these cases the anæsthetic is in a way protective. As Snow pointed out, chloroform "when carefully administered causes less disturbance of the heart and circulation than does severe pain." In this connexion it should be borne in mind that shock very often killed in pre-anæsthetic days, and it is not too much to say that if chloroform is ever the cause of death when properly administered, it is certainly very often the means of saving life by protecting from pain and shock. The safety of the patient lies in using a low (*i.e.* two per cent.) vapour of chloroform and lessening its strength as the operation proceeds; also in avoiding asphyxial complication, and this can be done by the use of oxygen.

Hypertrophied hearts are in practice usually *dilated* hearts, and being so they are working at a mechanical disadvantage. The same rules given for guidance above will serve here. Some highly nervous, excitable persons are much terrified by the application of a face-piece, and indeed in some few cases the mental distress and terror thus excited may be sufficient to occasion serious indisposition. In cases such as these it is especially useful to employ the A.C. mixture upon lint or dropped upon a Schimmelbusch's mask, replacing it by ether from an inhaler or given by a drop open method so soon as the patient is sufficiently dazed as not to perceive the substitution.

Vascular disease. *In arterial disease.* In aneurism and extensive disease of arteries it is best to use chloroform or one of the mixtures containing it, to avoid the increase of blood pressure induced by ether in the initial degrees of narcosis. It is as a rule quite safe to give ether after the patient has

been thoroughly anæsthetised and has been unconscious for some little time.* When apoplexy has previously occurred, or its onset is feared, ether had better be avoided and chloroform given. Cerebral hæmorrhage is reported to have occurred after ether had been inhaled, but the probability of such a result is slight. The danger in all cases of vascular disease arises from struggling and the consequent interference with the circulation. It is therefore most important to adopt such methods of giving the anæsthetic as will prevent or lessen the stage of excitement. This can be done by the use of nitrous oxide followed by ether, if this mixture be employed with judgment. On the other hand, there is certainly some risk in pursuing this course, since both nitrous oxide and ether tend to raise blood pressure, at all events in the initial stages of the period of induction, and this rise may be materially increased if any struggling or any other cause producing even slight asphyxia occurs. I have seen (*vide infra*, p. 125) one case of hemiplegia follow the use of nitrous oxide and oxygen in a man with no evidence of marked arterio-sclerosis, and when no asphyxial complication was perceptible. In the present state of our knowledge I should select the following method in these cases. A preliminary injection of morphine and atropine, with or without scopolamine, and followed by chloroform and warmed oxygen from a regulating inhaler or the A.C. mixture from a mask if it were desirable to avoid the firmly fitting mask requisite for the regulator. CONGENITAL HEART CONDITIONS. I have given nitrous oxide and oxygen to in cases of cyanosis without mishap. For major operations chloroform in low percentage with oxygen is the safest method to employ.

Renal disease.—Ether is said to produce albuminuria and

* I have notes of a very instructive case bearing upon this point. The patient suffered from popliteal aneurism for which it was proposed to tie the femoral. He was given nitrous oxide and ether, and narcosis was rapidly attained without struggling. Upon the patient being brought into the operating room the aneurism was palpated when all pulsation was found absent. The case was cured without any operation! No doubt the increase in blood pressure had led to disturbance in the circulation which luckily had resulted in clotting and filling up of the sac. Had, however, the other result occurred and the clot been conveyed to the heart the choice of the anæsthetic would have justly been considered a fatal mistake.

even cause suppression of urine. Lawson Tait recorded a case in which ether appeared to stop the flow of urine along the exposed ureter. Turnbull* says that Emmet of New York met with six cases in which suppression of urine occurred after operations under ether in persons with chronic nephritis. Professor Wood, of Philadelphia, also found cloudy swelling of the nuclei and contents of the secreting renal epithelium after etherisation of dogs. On the other hand Eisendrath, Barendseld, and Campbell of Montreal, found in human subjects that albuminuria was the exception after ether when previously non-existent, and that in pre-existing albuminuria a slight but transient increase followed prolonged etherisation. This conclusion is fully in accord with my own experience. Chloroform is more liable to initiate† albuminuria according to these observers. With the assistance of Dr. Levy I investigated this subject, and our conclusions may be stated briefly as follows‡: in most cases the quantity of the urinary water was reduced, but probably not more so than could be accounted for by the abstinence from food and liquids during the period of preparation for the operation. The solids remained practically unaffected. When ether is given in excessive quantity ischæmia of the kidneys is produced and albuminuria results. If, however, only so much is inhaled as is needed for complete anæsthesia no deleterious results arise, and the renal parenchyma is not injured nor does albuminuria result. The experimental work was supplemented by the study of clinical cases and these bore out our experimental deductions.

In conditions of collapse, *e.g.*, railway smashes, gunshot wounds, ruptured gastric or duodenal ulcers, intestinal obstruction due to strangulated hernia, or other causes, ruptured viscera, or conditions when the vitality has sunk very low, as in the case of carcinoma affecting the œsophagus, pylorus, and causing chronic starvation, also in collapse the result of severe hæmorrhages or other causes, or provoked by

* "Artificial Anæsthesia," 4th edit., 1896, p. 225.

† See "Complications of Ether," Chapter IV.

‡ *British Medical Journal*, Sept. 22 1900, "The effects of inhalation of certain anæsthetics on the kidneys.

high temperatures, it may be necessary to perform an operation, and it will usually be desirable to administer an anæsthetic. Ether if properly administered is, I am sure, the best and safest anæsthetic for these cases. It may be given from a Clover's inhaler, as when that apparatus is properly handled there need be no dyspnoea or impediment to respiration. Very little anæsthetic is required, and the mask may be taken off during inspiration every three or four respirations. At the present time a consensus of opinion favours the use of "open" ether for such cases, and provided due care is taken to avoid the employment of an excessive quantity by adopting a strictly drop method with a preliminary injection of atropine, this plan offers many advantages. It is important, however, that the patient should be guarded against cooling of his body, and that the head must be kept low. These patients are greatly benefited by intra-venous ether infusion. This plan not only supplies a small and readily controlled amount of ether, but affords a ready means of supplying the saline infusion which experience has taught us is so valuable under the circumstances. Dr. Willcox's suggestion of bubbling warmed oxygen through alcohol may be used as an adjuvant measure protecting against increased shock. When there is very considerable respiratory difficulty complicating the case, the A.C. mixture may be employed. Still ether is *par excellence* the anæsthetic for such patients. It is important to give plenty of air, and only to administer the ether intermittently as necessity seems to require. I have found the use of oxygen with ether most valuable under such circumstances. In extreme collapse, *e.g.*, railway smashes, the possibility of serious internal lesions and hæmorrhage must be kept in mind, as the incautious deepening of the anæsthesia may, under such circumstances, lead to serious results. A possible danger from ether in these cases arises when by increasing blood pressure internal hæmorrhage may be restarted. When the breathing is feeble and gasping, and the patient almost *in extremis* with blue livid skin and pulseless, I have for years been accustomed to employ ether dropped freely from a drop bottle upon a Schimmelbusch's mask covered with two layers of lint, keeping up a supply of oxygen by a mouth or nose tube, and

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this plan may be adopted as an alternative to the "open" ether method mentioned above, as it is perhaps more easily managed and less liable to lead to excessive quantities of ether being used. In cases of intestinal obstruction, when extreme collapse is present, I select ether and oxygen; if, however, collapse is less marked I prefer chloroform. In either case extreme care in regard to arranging the posture of the patient is requisite to avoid the regurgitation of intestinal fluid being aspirated into the lungs. Many authorities prefer spinal analgesia, or the recourse to local infiltration and regional analgesia for these patients. It is, however, very doubtful whether such methods are materially safer since fæcal drowning has occurred even when they were in use. Below (see Chapter X.) a method is suggested by which the air passages are blocked before the operation is commenced and the anæsthetic given either through an intubation tube or a tracheotomy aperture, while the stomach is continuously drained through a soft rubber tube kept in it until the operation is over. The alternative methods of **nitrous oxide** and **oxygen** or **ether intra-tracheal insufflation** are considered later. These procedures are not as yet sufficiently established for us to recommend them except in exceptional cases and in the hands of experts.

2. THE NECESSITIES OF THE OPERATION.

Operations about the head, neck, face, trachea, and respiratory tract.—In all cases of interference with respiration due to swelling of the structures of the neck, *e.g.* angina Ludovici, enlargement of the thyroid, in cervical lymphadenoma with pressure, nitrous oxide is contra-indicated. Ether, if given from an inhaler, usually causes dyspnœa, and so is best avoided unless it be given by an open method, but the depth of narcosis so obtainable, although adequate for operations on the head and neck, is insufficient for cases in which the nose and mouth have to be uncovered for some minutes. Chloroform given with great care is safest and best for the operator. Brief operations about the **mouth, nose, or pharynx**, such as the extraction of teeth, excision of tonsils, opening of abscesses,

* The precise way in which nitrous oxide should be given, *e.g.*, with oxygen, air, etc., will be dealt with in Chapter III.

chloroform and ask for a profound narcosis to prevent palatine movement and rigidity of the faucial arches. This, however, can only be accomplished with some risk as the very nature of the operation causes some obstruction to respiration, so that the utmost care is necessary.

For most intra-nasal operations I have found nitrous oxide and ether following atropine satisfactory. It may be necessary in very prolonged cases to give more than one inhalation of ether, but there is no objection to this if care be taken, by turning the head to the side, that blood does not enter the lungs. When the patient is sitting up, I bend the head and shoulders forward during the re-application of the ether. It is better to wait for a return to consciousness before giving the second inhalation. When the surgeon wishes his patient to be seated, chloroform should not be given. Snow, it is true, believed that the sitting posture was as safe as any other, but there can be little doubt that in such a position the heart works at a disadvantage, and cerebral anæmia is very prone to occur. Some surgeons prefer chloroform for all patients when the naso-pharynx is the seat of operation, since they allege this anæsthetic produces (i.) a more profound and lasting anæsthesia, and (ii.) because less violent bleeding takes place at the time of the operation. On the other hand, the rapid resumption of consciousness under ether certainly minimises the danger of blood entering the lungs. When the operation is likely to prove a prolonged one, chloroform will be more satisfactory to the operator, but the patient must be in a recumbent position. I have adopted the plan of giving morphine with atropine, sometimes adding scopolamine before chloroform for these cases, and find that when anæsthesia is once induced, the preliminary injection enables one to maintain an excellent anæsthesia with very little anæsthetic. The drawback to this plan is that the patient remains profoundly drugged for some hours after the operation, and requires careful watching, lest in the event of there being hæmorrhage, the blood should enter the air passages.

Staphylorrhaphy necessitates the mouth being open, and that the operator should have free and uninterrupted access to the buccal cavity. To effect this, the patient can be put under the influence of chloroform, and maintained so by

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anæsthetising through the mouth by means of a tube (as described in Chapter VIII.). The same procedure answers for operations about the **tongue**. For the removal of small growths from the tongue, lips, or from the gums, I have found nitrous oxide answers well. The method of prolonged nitrous oxide administration through the nose gives the operator a much longer period of unconsciousness. (See also Chapter III.)

In Kocher's operation for the **removal of the tongue**, ether can be used when it seems desirable until quite the end of the operation when the mucous membrane of the mouth is opened and the tongue is dragged into the incision.

Removal of the upper jaw should, as a rule, be performed under chloroform, as the cautery is often requisite and the use of a face-piece impossible. There are, however, the alternatives of infusion of ether or hedonal or rectal etherisation, and the chapters dealing with these methods may be consulted for further information. In extensive removals of growths about the jaws, it is frequently advisable to perform a preliminary tracheotomy, and then give the anæsthetic through a Trendelenburg's tube, at the same time plugging the larynx. It is, however, quite possible to obtain a most satisfactory anæsthesia with ether, which allows removal of either jaw (see Chapter VIII.). I have occasionally used ether in these cases with success, and I am informed this method is employed as a matter of course in some clinics in the United States.

In the **removal of the lower jaw**, ether may also be used for the earlier stages of the operation, chloroform being substituted when the mouth has to be opened. In any case, when the cautery has to be used, the ether must be replaced by chloroform. In asthenic, feeble subjects it is an advantage to induce anæsthesia by an ether sequence, using atropine as a preliminary, as this anæsthetic provides a valuable stimulant, counteracting the depression of blood pressure which occurs when chloroform replaces the ether.

Operations upon the **larynx**, *e.g.* **laryngectomy**, will require preliminary tracheotomy, and in these cases I prefer to keep up the anæsthesia by a Junker's inhaler, to the efferent tube of which is fixed a catheter. By this means the amount of chloroform given can be more safely adjusted than

when a Hahn's tube and funnel are employed. For bronchoscopy, chloroform or a mixture is perhaps the most satisfactory anæsthetic. In all the above cases in which chloroform is mentioned as being more convenient, alternative methods exist, namely, ether infusion and rectal etherisation.

Operations about the **eyes** are commonly performed with the aid of cocaine, β -eucaïne, or some local analgesic (see Chapter XI.); when general anæsthesia is decided upon, and it is often necessary in the case of children and excitable nervous or asthenic persons, it is important to obtain deep narcosis. These cases require absolute immobility, freedom from coughing being essential. Nitrous oxide alone or with ether, provided the ether be pushed very far, answers well; there is, of course, the possibility of ether exciting a fit of coughing, which, should the case be one of removal of a cataract, and should a preliminary iridectomy have been already done, may lead to forcible extrusion of the vitreous. But this can only arise when the patient is not sufficiently under the anæsthetic. There is less fear of coughing with the use of a chloroform and alcohol mixture. I have used the oxygen-ether method very satisfactorily for these cases. Upon the whole I think when the patient is old and feeble, and the respiration in any way impaired by former attacks of bronchitis, that chloroform offers the best chance of a successful operation.

In **excision** of the **eyeball**, where coughing is not of such moment, ether may be used, and should be pushed to complete anæsthesia before proceeding with the operation. For passing probes or slitting up the lacrimal canals, gas is not as a rule satisfactory, as the jactitation interferes with the operator; here the use of ethyl chloride or gas and oxygen answers every purpose by obviating involuntary movements.

For **operations** about the **thorax**, a mixture of chloroform and ether is by some authorities considered to be more advantageous than chloroform or ether when given alone. My experience, however, is that chloroform given with oxygen, provided the dilution of the chloroform is kept low, causes less distress and provides a better anæsthesia than any other drug. For paracentesis in cases of pleuritic effusion

ethyl chloride or nitrous oxide gas is sufficient. Chloroform, unless a very low percentage vapour is used, seems peculiarly liable to dangerous results in cases of empyema; the heart is usually hampered and respiration abnormally performed; several deaths have resulted from chloroform given in such cases. When the bronchial tubes are not blocked with pus and no communication exists between the abscess and the bronchi, ether will occasionally be well borne, but as a rule a low percentage of chloroform vapour is, I think, safer. In cases in which a plus intra-thoracic pressure is requisite the intra-tracheal ether method appears to offer especial promise. Mr. Morrision Davies advises the employment of his plus pressure machine with chloroform given dosimetrically together with oxygen.*

It is in these operations that rectal etherisation seems likely to be of very great service. But unless atropine is used there is a danger of increased bronchorrhœa causing suffocation. I adopted this method without, however, giving atropine, for a patient at the Brompton Hospital for Consumption some years ago, and very grave filling up of the bronchi with fluid occurred. It is probable that the narcosis was too deep, and that the empyema had established a communication with a bronchus. Prompt inversion enabled the fluid to escape, and the operation was successfully completed. (See "Etherisation by the Rectum.")

Abdominal surgery.—In dissecting operations, when tranquillity of respiration is desired, as in operating for the radical cure of hernia in young children, some mixture of chloroform with alcohol or ether may be employed instead of ether, but for all prolonged and exhausting operations ether should be given unless strongly contra-indicated. Open ether answers admirably, especially when used after alkaloids. In all septic cases ether rather than chloroform should be selected, as evidence exists that the tissues react towards recovery far better with the former than with the latter anæsthetic. Thus I have found for appendectomies, operations upon the stomach, intestines, and liver, as well as for Cæsarian sections, ovariectomies, and hysterectomies, ether, if carefully given, answers very well. It is undesirable to

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continue the ether for more than forty-five minutes or an hour unless the patient cannot take chloroform. After this time a chloroform-alcohol mixture or chloroform may be used.* If one kidney is presumably adequate and healthy, ether may be used in nephrectomy. For operations upon the liver and gall bladder, for those upon the intestines and stomach, chloroform or a chloroform-ether mixture makes the operation easier for the surgeon, and subjects the patient to less risk of pulmonary complications. Still with care in the use of ether such operations can be performed when the patient's state seems to contra-indicate the employment of chloroform. Many of the objections to ether disappear if it is associated with atropine and is given guttatim on an open mask. Very prolonged abdominal operations, if done under ether, are not free from a risk of ether after-effects such as collapse due to over-stimulation as well as the well-recognised pulmonary dangers, so that I think it is wise to discontinue the ether as time goes on and employ chloroform, but always dosimetrically and associated with oxygen. As will be seen when the article on the use of nitrous oxide and oxygen in major surgery is read, some authorities recommend that in practically all cases in which chloroform or ether is commonly used, they can be advantageously replaced by nitrous oxide and oxygen, but they recommend the preliminary employment of alkaloids, and at times add ether vapour to effect muscular relaxation. The adoption of intratracheal etherisation, the infusion of ether or other drugs, and the method of spinal analgesia provide alternative methods. As these procedures require special apparatus with a special technique, and have not been universally accepted, I must refer the reader to the special articles dealing with these proceedings.

In labour.—There is a consensus of opinion in favour of chloroform in these cases, but chloroform cannot be in any way deemed more free from danger in childbirth than at any other time. If chloroform be employed it should not

* It is alleged that ether pneumonia is especially liable to occur in abdominal operations. See "Ether Pneumonia," by Dr. David Drummond, *Brit. Med. Jour.*, Oct. 1, 1898, p. 939. This subject is discussed freely below in the chapter dealing with ether, and the reader is advised to refer to that section.

be entrusted to the hands of a nurse or other person unless skilled in its use. The Vernon Harcourt inhaler answers very well in these cases. The mixtures of chloroform and alcohol and ether also answer well. Ether, though advocated by some, is disadvantageous in these cases, as it may provoke straining, coughing, sickness, and headache,* but for general obstetric operations, and especially where the patient is exhausted and needs stimulating, ether is indicated, and may be given by the "open method."

Although no experimental evidence exists so far as I know for the statement, yet it is commonly asserted that chloroform is safer for the child than ether. A point worth remembering is this, that the more agreeable smell of chloroform and its rapidly soothing effect makes the patient inhale it freely as the pains are coming on without any holding of the breath.

THE PROCEDURE DURING AN OPERATION AND THE RECOVERY.

The routine to be pursued varies in the different types of operation, and is considered fully in Chapter VIII.

It may be said here that for all cases the anæsthetist has to study the posture of his patient in so far as this interferes with respiration, and when a bad posture from his point of view is rendered necessary for the surgeon's manipulations, he must lessen the strength of the vapour he employs to avoid hampering breathing still more, and use oxygen to antagonize the air deprivation which arises. The position also must be studied so that pressure upon the nerves or vessels of the neck, arms, and lower extremities may be obviated, and so post-operative palsy may not occur. The maintenance of the body's temperature is also essential to its avoidance of a chill through the change of room when the patient is conveyed back to bed.

* In my private practice I have met with cases of women who after trying chloroform preferred to take ether in their confinements, stating that it produced more exhilaration and general feeling of wellbeing, while it assuaged their pangs more efficiently than chloroform.

CHAPTER III.

NITROUS OXIDE GAS.

NITROUS OXIDE.

Chemical and physical properties.—Nitrous oxide (N_2O) is a colourless gas with a faint smell and slightly sweet taste.

A convenient mode of preparation is to heat dry ammonium nitrate; the salt melts at about $165^\circ C.$, and begins to decompose at about $185^\circ C.$ The decomposition proceeds rapidly between $200^\circ C.$ and $240^\circ C.$ A well-dried mixture of ammonium sulphate and sodium nitrate is frequently used instead of ammonium nitrate because the decomposition proceeds quietly and more uniformly.

When required for anæsthetic purposes the gas is purified from chlorine (formed from traces of chlorides in the ammonium nitrate) by passing the gas through a solution of potassium hydroxide, and from nitric oxide by passing the gas through a solution of ferrous sulphate.

The vapour density of nitrous oxide is 1.5299 (air = 1), 100 c.c. of water at $0^\circ C.$ dissolves 130 c.c. of the gas, at $20^\circ C.$ it dissolves only 67 c.c., hence the gas is collected over hot water in order to lessen the loss due to its solubility. The gas condenses to a colourless limpid liquid at $0^\circ C.$ under a pressure of 30 atmospheres. Liquid nitrous oxide can be purchased in steel cylinders. The liquid boils at $-89.8^\circ C.$, and freezes to a snow-like mass when allowed to evaporate; the solid melts at $-102.7^\circ C.$

Nitrous oxide gas possesses well-defined anæsthetic properties, which appear to be quite distinct from the asphyxial symptoms frequently associated with its administration.

This gas supports combustion when ignited bodies are plunged into it. Fifty gallons of the gas are yielded by 15 oz. of the liquid nitrous oxide. It is extremely sensitive to heat, undergoing rapid expansion as its temperature is raised. This is a point of practical importance, as cylinders of this gas are liable to burst if subjected to undue heat; indeed this accident has occurred.

Nitrous oxide is decomposed at a red heat, but shows no tendency to undergo change at lower levels of temperature.

It has long been known that if the gas from a steel cylinder be allowed to escape suddenly, it assumes the solid form and may block the outlet. This is more liable to occur when the cylinders are placed horizontally, but when the exit tube is placed with its inner end above the level of the liquid nitrous oxide, this drawback is obviated.*

Some persons prefer the freshly prepared gas, but liquefied gas stored in cylinders gives results practically as good.

PHYSIOLOGICAL ACTION OF NITROUS OXIDE.

For many years the true nature of the action of this gas upon the organism was misunderstood.

The theory that it acts by producing hyperoxidation is disproved by the proved fact that nitrous oxide is not split up in the tissues. A more dangerous view advanced was that nitrous oxide exercised no specific action but mechanically displaced oxygen from the lungs and so led to tissue asphyxia. The late Sir George Johnson, following the remarkable experiments of Dr. John Reid, was led to the conclusion that nitrous oxide, by producing deoxygenation of the blood and tissues, set up arterial spasm both in the systemic and pulmonary vessels. The increased resistance to the blood flow thus brought about led, he thought, to lividity, failure of the radial pulse, and finally through cerebral anæmia to epileptiform convulsions. Dr. Amory, of Boston, also held this view. Professor H. C. Wood†

* See Dr. Sheppard's paper, *Lancet*, Feb. 21, 1891.

† *Therapeutic Gazette*, Aug. 1890.

assisted by Dr. David Cerna has made important observations on this subject. Their paper must be consulted for details; their conclusions alone can be briefly noticed here. They regarded the action of nitrous oxide and nitrogen as similar, but found that nitrous oxide produces anæsthesia probably more rapidly, and does so by "shutting off the oxygen." Although no reference is made to my experiments, their conclusions with regard to the circulation of the blood under nitrous oxide are very strikingly in accord with mine. "It would seem," they say, "as though nitrous oxide acts upon the heart and nervous system directly, but has little or no direct inherent influence upon the vaso-motor centres or the brain cortex." In comparing the effects of these gases with the effects brought about by asphyxia, it is admitted that the resemblance, which so many preceding observers had erroneously regarded as identical, is only noticeable to a certain extent. There is little doubt, however, that in the observations cited, insufficient care was taken to discriminate between the phenomena due to a deprivation of oxygen and those due to nitrous oxide given without any associated asphyxial complication.

If oxygen is excluded for too prolonged a period, of necessity the phenomena of oxygen deprivation will make themselves manifest. If, as has been assumed, no anæsthesia can result until this oxygen starvation exists, the question is settled, but such is not the case. Indeed the classical experiments of Paul Bert proved this. I pointed this out in my research,* undertaken in 1885, and Wood and Cerna have since then undertaken experiments with nitrous oxide mixed with oxygen. When the supply of oxygen is carefully regulated the most profound anæsthesia associated with normal pulmonary and systemic circulation results. Under these circumstances no question of tissue deoxygenation arises, so that it must be admitted that however asphyxial symptoms may, through want of expertness, play a part in some forms of nitrous oxide anæsthesia, yet the gas in question certainly possesses a specific effect upon nervous tissue and exerts that influence through the blood.

* *Transactions Odontological Society*, vols. xviii. and xix., on the "Physiological Action of Nitrous Oxide Gas."

Nitrous oxide appears to suspend rather than abolish function. Seeds will not germinate but remain uninjured when kept in it for an indefinite period. Seeds, if sprouting, cease to develop when placed in an atmosphere of this gas, but resume their growth when again placed in the air. Jolyet and Blanche found that plants placed in nitrous oxide gas cease to absorb carbon dioxide, and do not increase in size. When oxygen is allowed to mix with the nitrous oxide the seeds germinate, and the plants grow. Cold-blooded animals die in an atmosphere of nitrous oxide in about two hours. This contrasts with what obtains when the same creatures are placed in indifferent gases, such as hydrogen or nitrogen, for under these circumstances death does not occur for three hours, and is preceded by stupor but not true anæsthesia. Kappeler has shown that frogs placed in nitrous oxide lose reflexes after a very few minutes, whereas the reflexes persist for several hours when the frogs are placed in an indifferent gas, *e.g.*, nitrogen (Goldstein). Sir Humphry Davy, in his careful research, showed that small mammals and birds soon die in nitrous oxide, although when it is mixed with oxygen they live until the oxygen tension sinks to six per cent., as against a carbon dioxide tension of twelve per cent.

Animals placed in non-respirable indifferent gases become convulsed before death; this does not obtain when they are made to respire nitrous oxide, provided asphyxial conditions are not present. Their respirations simply grow more and more shallow, and finally cease without any of that *besoin de respirer* which is elicited when simple deprivation of oxygen is practised.

Krishaber experimenting with rabbits found a marked acceleration of the rate of the pulse, with increased force at first in the heart beat. Subsequently when anæsthesia was determined some retardation occurred, while the cardiac rhythm became less regular. Respiration was accelerated, and death resulted in two or three minutes. He performed control experiments by ligaturing the trachea. In these, cardiac rhythm remained unchanged until after the fourth minute, when the heart beats grew irregular, and ceased at

times varying from seven to eleven minutes. The animals remained sentient to the very last. I have repeated these experiments, using dogs and cats in preference to rabbits, because these last are peculiarly liable to fright, and fear disturbs the rhythm alike of the heart and respiration, and in the main my results agree with Krishaber's. While dogs die in from two to three minutes in nitrous oxide, they do not succumb to asphyxia for five; under nitrous oxide they grow wholly insentient in from fifteen to thirty seconds, while in asphyxia consciousness to pain only ceases with life. Under nitrous oxide I found the heart little affected until the respiration was gravely interfered with, in other words until asphyxial conditions were present, and then it gradually failed before totally stopping. The creatures seemed under the gas to sink into sleep, and from sleep to pass into death, while when asphyxiated they struggled from first to last.

In the human subject.—It is probable that nitrous oxide, when administered pure, enters the blood by diffusing through the thin walls in the air-cells in the lungs. In the blood, a small quantity is dissolved, but the bulk is aggregated in some loose way with the blood constituents, probably being associated more or less closely with the proteids of the liquor sanguinis and corpuscles. Pickering has, in an interesting research, corroborated the view which was suggested by me in the papers referred to above, that nitrous oxide is taken into a loose association with the hæmoglobin of the blood.* Dr. G. F. Kemp† of Baltimore has performed experiments which support the views I advanced in 1885 (*vide supra*). According to Herman, nitrous oxide destroys the red blood corpuscles. Turnbull, however, has experimentally shown that the corpuscles do not give evidence of any change after inhalation of nitrous oxide. I carefully watched the corpuscles in the web of a frog's foot, while the frog was in a bell-jar of nitrous oxide, and was able to observe not only the phenomena of the circulation under these conditions, but also to satisfy myself that no breaking up of corpuscles was evident. The actual changes in the gases of

* Cf. the theory of the aggregation of chloroform with the erythrocytes of blood advanced by Moore and Roaf. See p. 225.

† *Brit. Med. Jour.*, Nov. 21, 1897.

the blood under nitrous oxide were examined by Dr. Thomas Oliver * and Mr. F. C. Garrett, but they, like other observers, do not seem to have been sufficiently careful to obtain an analysis of blood when charged with nitrous oxide, but yet not so deoxygenated as to be practically asphyxial blood containing nitrous oxide. Their results are :—

(Normal Dog).	Before Inhalation.			After.
Carbon Dioxide	...	34·3	...	15·66
Oxygen	...	22	...	3·49
Nitrogen	...	1·8	...	11·23
Nitrous Oxide	...	—	...	22·49.

The effect of shaking arterial blood with nitrous oxide gas *in vitro* is to darken it, showing that nitrous oxide gas is able to displace oxygen. But whatever union does take place between this gas and the blood constituents is very unstable, since blood parts at once with its nitrous oxide when left in free contact with oxygen or air.

RESPIRATION AND CIRCULATION.

Under prolonged inhalation of nitrous oxide, the respiration becomes slowed and shallow, and, if the gas be pushed, a complete cessation of respiratory movements eventually takes place. The amount of tissue change is lessened, hence the quantity of carbon dioxide which the lungs give off is diminished. Subsequently to the administration, the exhalation of carbon dioxide is increased. The **heart** beats quietly, fully, and regularly under this gas; the pulsations are somewhat slowed in profound narcosis. Healthy persons incur but slight danger of heart failure from its inhalation. In animals killed by nitrous oxide gas, the heart goes on beating even after the respirations have quite ceased. It is, therefore, less important to watch the pulse than the respiration. Blood pressure is somewhat increased, and markedly so in the brain and cord, the vaso-motor system of different areas being, it would appear, diversely affected. This altered pressure is, however, usually but slight. Dr. George Oliver has made

* See *Lancet*, Sept. 23 1893, p. 683, for Dr. Oliver's conclusions.

some important observations upon the variations in blood pressure under anæsthetics. By the use of his arteriometer, he found that when nitrous oxide was given alone, if it were pushed to a stage in which asphyxial symptoms began to show themselves, it caused "a slight expansion of the calibre of the artery followed by a reduction either to the normal calibre or to a point or two below it," although, "the drop below the normal need not take place," *i.e.*, when a simple nitrous oxide effect takes place. When oxygen is given with the nitrous oxide no reduction of the normal calibre takes place.

The rise of blood pressure under nitrous oxide, although slight, may become much accentuated if any asphyxial factor is allowed to intrude. This is a very important matter to bear in mind when the patient suffers from an abnormal height of blood pressure, *e.g.*, in cases of arterio-sclerosis.

In some observations I made upon this subject, I found that while asphyxia caused diminution of the bulk of the brain and cord, nitrous oxide produces so great an enlargement as to force out the cerebro-spinal fluid. There can be no doubt these changes are vaso-motor in origin, and explain many of the nervous phenomena elicited in persons narcotised by nitrous oxide.

NERVOUS SYSTEM.

The senses of a person passing under nitrous oxide are at first rendered somewhat more acute, after which follows a condition of analgesia. During the first degree of unconsciousness, a loose tooth may be extracted without pain, although the patient has a vague idea that something is being done. A few seconds later, and the individual is profoundly unconscious and insensitive to all his external surroundings. Irregular discharges of nervous energy frequently show themselves at this stage in jactitations of the arms and legs. These movements are probably due to the deprivation of oxygen, as the admixture of air or oxygen before they develop effectually prevents their appearance. If nitrous oxide gas continues to be respired and oxygen is excluded, the limbs become rigid, the rigidity being every second or two broken by a sudden contraction of the flexors. Rhythmic tremors of

hands and arms are occasionally elicited. More rarely the whole body of the patient arches backward like a bow (opisthotonos), jerking him out of the chair. Mr. Clover recorded a case of an adult who jerked himself completely out of the chair in this way. This condition is especially liable to occur in children. The muscles relax to some extent when asphyxia is relieved. The degree of rigidity and the amount of jactitation vary in different cases; children show jactitation early, and the movements of the limbs are more marked in them than in adults. The superficial reflexes are abolished, that of the patella tendon, however, persists; and in many cases ankle clonus is developed under nitrous oxide.* The pupil usually undergoes wide dilatation when complete anæsthesia is attained, but this phenomenon is not absolutely constant and is not an indication of danger. The eyeballs seldom become fixed and conjunctival reflex is not invariably lost, so that "ocular phenomena" are an indifferent guide in judging whether anæsthesia is developed. Nitrous oxide mixed with air or oxygen causes no muscular movements. Nitrous oxide associated with oxygen, when given through long periods as in surgical operations, is apt to induce a stiffness, sometimes amounting to rigidity, which constitutes an objection to its use for long operations in general surgery. It has been shown that the elimination of carbon dioxide is lessened during the inhalation of nitrous oxide, so that it is only reasonable to expect some effects of accumulation of this gas in the blood and tissues. As Mr. H. Paterson has pointed out it is probable that "a process of internal asphyxia" may occur.†

During the condition of hyperæsthesia which precedes anæsthesia, the patient is often affected by hallucinations, frequently of an erotic nature, and the impressions then received remain firmly imprinted upon the brain. The difficulty of convincing persons that such impressions are not realities should lead every administrator to secure independent evidence of his actions while his patient is unconscious. The bladder and even the rectum may be involuntarily emptied

* For further particulars on this point, see a paper by the author on "Ankle Clonus under Nitrous Oxide," *Brit. Med. Jour.*, Sept. 24, 1887.

† *West London Medical Journal*, 1899, p. 204.

under nitrous oxide, especially in nervous persons, or if the anæsthetic is pushed, and hence it is always wiser to allow patients to pass urine before taking this anæsthetic. As a rule, the alimentary tract is unaffected by nitrous oxide, but nausea, vomiting, and bilious derangement, may occur after its administration. In view of the possible occurrence of this trouble, it is well for patients to abstain from food immediately before taking nitrous oxide gas.

Later effects, which are said in some instances to ensue from the gas, are various functional derangements of the nervous system, tinnitus aurium, headache, and amaurosis, but these conditions occur only with the most exceptional rarity.

Laffont, arguing from a somewhat limited number of cases, considers that the effect of nitrous oxide is to produce untoward complication (1) in pregnancy, (2) at the menstrual epoch, (3) in persons subject to nervous disorders, (4) in diabetes, on account of the prejudicial effects of deprivation of oxygen in these conditions. As will be pointed out later, his contentions are fully met if we adopt the correct method of giving nitrous oxide, which is to avoid any asphyxial complications.

It may be said generally that our present knowledge of the physiological action of nitrous oxide goes to show that that agent has not any deleterious action in itself. It is a heart stimulant, and is free from any irritant action on the lungs; it does not interfere with the functions of digestion or of the kidneys, but if given without sufficient care or knowledge bad results may accrue through the supervention of symptoms due wholly and solely to the accompanying but unnecessary deoxygenation of the blood and tissues.

Duration of anæsthesia.—The induction period of anæsthesia by nitrous oxide varies, but it is about 55 seconds. The duration of anæsthesia is for anæmic persons and children about 30 seconds, for adults 40 to 45 seconds. When given with air or oxygen, the duration of workable anæsthesia is longer, as the operator can depend upon immobility throughout the whole period of unconsciousness.

The greater the amount of gas inhaled, the longer will be the period of anæsthesia, so that provided the patient is

respiring freely all the time, a longer period of induction leads to a longer anæsthesia. Persons with a large vital capacity take most ; children, feeble and anæmic people least ; these last come rapidly under the influence of the anæsthetic, and as rapidly resume consciousness. Such people are good subjects for nitrous oxide combined with air or oxygen, as it allows them to inhale sufficient of the anæsthetic to render their blood saturated to the required extent for an effectual anæsthesia.

CHOICE OF METHOD OF GIVING NITROUS OXIDE FOR VARIOUS OPERATIONS.

In very brief operations, occupying less than half a minute, nitrous oxide may be given by mouth inhalation. When the patient is weakly, anæmic, cyanosed, or congested in appearance, or is a child, it is better to employ mixtures of nitrous oxide with air or oxygen. These mixtures are also better for operations requiring more time, as usually an additional ten seconds or so of available anæsthesia for operating are thus obtained. In longer dental operations the nasal method gives as much time—ten or fifteen minutes in favourable cases—as is usually needed. The alternative methods for such prolonged operations are: nitrous oxide followed by ether ; ethyl chloride by itself, or given with nitrous oxide. Nitrous oxide, with air or oxygen, can be given for major operations, even those upon the mouth, nose, and oro-pharyngeal area ; but these require a special apparatus and technique, and are dealt with later on in the section (p. 118).

IN DENTAL SURGERY.

Nitrous oxide alone, or combined, is the safest and probably the best anæsthetic for this branch of surgery. When nitrous oxide is used alone, and pushed to the point of stertor and jactitation, two or three teeth may be extracted at one sitting, and expertness in operating may, in some cases, enable many more to be removed. Abnormality of the teeth or mouth may render extraction so difficult as to prevent the successful removal of even one tooth at a sitting, and in all instances it

is better not to promise the extraction of several teeth unless the case is manifestly an easy one. The operation should never be continued when the patient is becoming conscious, otherwise he will complain that he perceived the removal of every tooth; to obviate such mishaps, an operator would do wisely to place himself in the hands of his anæsthetist, who will generally be better able to judge how much may be done with impunity. Unless some special reason exists for desiring to extract several teeth at one sitting, it is advisable to let the patient attend twice or thrice, rather than to subject him to more than one administration on the same day. Extracting a number of teeth simultaneously produces more or less severe shock, and should be avoided, therefore, when possible. When it is necessary to perform an extensive operation at one sitting, one of the plans suggested below (p. 91) may be adopted.

Nitrous oxide may be given :—

By inhalation from a bag through a valved face-piece.

By the "open method" (Flux).

By mouth injection (Coxon).

By nasal methods.

In combination with oxygen.

In sequence with ether.

In sequence with ethyl chloride.

THE ADMINISTRATION OF NITROUS OXIDE GAS.

The simplest apparatus employed consists essentially of one or two cylinders of compressed gas placed horizontally. The cylinders are made to hold either 100 gallons, 50 gallons, or 25 gallons. Roughly 50 gallons of N_2O may be taken as weighing 15 ounces, so that, knowing the weight of the cylinder when empty, the amount of gas remaining in the cylinder can be readily read off by weighing the cylinder. The two cylinders are yoked together by a connexion the free end of which is screwed to a further metal mount carrying a length of tubing which is attached at its distal end to the gas bag. This tubing may be made of metal or of rubber, strengthened by coiled wire to obviate kinking or compression if trodden upon.

To prevent the noise of the outrushing gas a "silencer" is sometimes attached to the yoking connexion, but is usually unnecessary, as a little care prevents the noise. The gas bag (Cattlin's bag) is made of rubber and should be capable



FIG. 1.—Yoked nitrous oxide cylinders with Cattlin's bag, face-piece, and metal valved connexion supported on stand.

of containing two and a half or two gallons of gas. The face-piece, which should fit accurately, is connected with the gas bag by a metal mount containing both inspiratory and expiratory valves to prevent the patient's exhalations fouling

the bag. Mr. Vernon Knowles has devised a reversible bag (fig. 2) which can be turned inside out after washing and sterilising, so that each patient breathes into a sterile bag. When tuberculous, syphilitic, or other obviously septic persons are concerned, it is wise to employ an all-metal face-piece



FIG. 2.—Mr. Vernon Knowles' reversible bag.

instead of the usual rubber one, since the latter cannot be boiled without destroying it (see fig. 3).

The two stopcocks figured below are simple and allow easy access to the valves, which is essential, since all rubber material is apt to perish unless constantly in use, and unless

kept at a moderately warm temperature (figs. 4 and 5). It is useful to powder the bag, the face-pieces, and so on with French chalk and boric powder after cleansing, as this obviates the rubber sticking together and maintains a smooth surface.

When the gas supply is taken from a large gas container this is connected with the bag and face-piece by an adequate length of tubing.

After use the cylinders should be carefully examined to ascertain whether the exit is fully closed. Any escape may be detected if a film of water be smeared over the free end, since, if there is any escape of gas, a bubble will form.



FIG. 3.—All-metal aseptic face-piece. (Weller's.) For septic cases.

The most convenient shape of cylinder is that with an angle attachment provided with a foot-piece (fig. 1). This latter is usually more under control than is the case when a hand key is used. Various mechanical contrivances have been made which obviate the turning on the gas supply by rotating the foot-piece, but they are not at all necessary.

A few words may be said about face-pieces. Personally, I prefer those made of rubber, of the shape designed originally by Clover, and furnished with an air cushion (fig. 4). Three sizes are usually required—one for children, also a medium, and a large. If an expiration valve exists in the stopcock of the

mount attached to the Cattlin's bag, none is required in the face-piece. Celluloid and metal face-pieces (figs. 1 and 5) fitted with removable air cushions are not satisfactory, as after a little use the cushion does not apparently prevent a leakage of gas or air. The advantage claimed for the celluloid mask is certainly actual—it allows the anæsthetist to see the mouth of the patient, and so enables him to detect vomiting or other untoward accident.

Coleman's stopcock (fig. 5) enables the anæsthetist to give definite quantities of mixtures of gas and air. This



FIG. 4.—Face-piece, stopcock, and gas bag for the administration of nitrous oxide gas only. (Sir F. Hewitt's apparatus.) The handle H opens or closes the air way while it closes or opens the supply of gas from the bag. The tap marked T when rotated closes the expiratory valve and allows of rebreathing. The arrows indicate the course followed by air or gas.

is effected by the "see-saw" aluminium plate valve which is in conjunction with the seats of the air and gas apertures. Under the movement of the handle H, the aluminium plate valve opens and closes both inlets to the mixing chamber and thus admits air or gas singly or mixed in various proportions according to the position in which the handle is set. To operate the stopcock when administering nitrous oxide, fix the handle H at position I for air, and turn it upward to position H for gas. For mixtures of gas and air gradually turn the handle H down towards I, which will admit the desired amount of air.

SUBSIDIARY REQUIREMENTS.

Gags, mouth openers, dental props, tongue forceps, oral spoon, a tracheotomy case, sponge holders, tincture of iodine, and sterilised mops should always be at hand before the administration commences.



FIG. 5.—Three-way stopcock. (Mr. F. Coleman's principle.)

- F P Face-piece.
- E V Expiratory valve (rubber).
- I V Inspiratory valve (aluminium).
- A A Air aperture.
- G I Gas inlet tube to which the Cattlin's bag is attached.
- H Handle set for nitrous oxide.
- 1 Handle set for air.
- 2 Handle set for rebreathing into bag.

Gags.—The one figured has special advantages from the facility it offers for rapid removal and replacement. In it the screw-fixing arrangement is replaced by a ratchet.

By putting the finger upon the free end of the ratchet and pressing it backwards as one does a trigger, the ratchet is released and the gag closes. To open it, it is only necessary to press the handles together and the

ratchet will automatically gear and prevent closing of the mouth. The ratchet arrangement can be used with long or short handles; personally I prefer the latter. With long handles such powerful leverage is obtained that teeth may be easily forced out of their sockets or snapped off if they are at all brittle. If the jaws of the gag



FIG. 6.—Gag fitted with ratchet arrangement. (Dr. Dudley Buxton's pattern.)

(W. B. Ackland) are placed on the same plane, the gag is more easily introduced but is more liable to slip.

Of mouth openers, Heister's, figured below, is the best. It possesses enormous power, so it must be used with care. Its employment is indicated in cases of severe trismus, partial ankylosis, etc. The blades may be inserted either in a gap



FIG. 7.—Mouth opener. (Heister's.)

caused by the previous extraction of a tooth, and, if possible, between the molars. If placed between incisors great risk is run of forcing these teeth out of their sockets. Various mouth openers made of wood or metal, tapering so as to act as a wedge, are in use, but need no special mention.

Dental props.—Mr. Clover employed those made of hard

wood, but, although very convenient and not liable to slip, they are apt to get chipped and split.

The cleanest and nicest I know are those figured below and made of vulcanite. The shank is strengthened by a metal



FIG. 8.—Vulcanite mouth prop.

tube, about which the hard vulcanite is placed. The ends are ridged and grooved to prevent slipping.

The mouth prop spoken highly of by Mr. A. S. Underwood

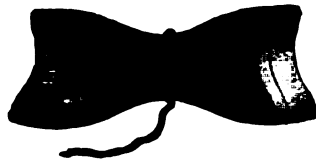


FIG. 9.—Mouth prop. (Underwood.)

and figured above is also useful. It has a soft pad at either extremity (fig. 9).

Although spring and mechanical props are objectionable upon the general ground of their liability to get out of order



FIG. 10.—Sir F. Hewitt's mouth prop.

or to break, yet some kinds are useful, and I subjoin illustrations of some of the best.

Sir F. Hewitt's props (fig. 10) are serviceable. They are made of metal, shaped to fit between the upper and lower

teeth, and have removable india-rubber caps on their extremities. Except in cases in which the wedge has to rest on the gum, I think the rubber caps are undesirable, and prefer to employ props of the same shape as the one figured made wholly of nickel-plated metal, with the surfaces cupped to hold a biting surface of lead. This, although it does not chip, allows the teeth to grip slightly into it. The narrow end of the wedge is placed towards the pharynx, and the horizontal surface should rest on the mandibular teeth.



FIG. 11.—Weller's gag.

A central prop, fixing upon the anterior teeth with a rotating arm, permits of operations upon one or other side of the mouth according to the necessities of the case. A very convenient form is figured above (fig. 11). It possesses an easily working screw, which permits of very nice adjustment. The plates should rest upon more than one tooth in each jaw.

No mouth prop or cork should be placed in the mouth without being first securely tied to a counterpoise which hangs out of the mouth, and prevents the prop becoming wedged in the larynx or œsophagus in the event of its slipping. Several sizes are required, and these can be care-

fully tied together with strong fishing cord; the chains often used are apt to snap. The few minutes spent in carefully adjusting the prop between the teeth should not be grudged,



FIG. 12.—Mouth spoon. (Dr. Dudley Buxton's pattern.)

as the after success of the operation depends largely upon the security obtained by this-manceuvre. It should be adopted

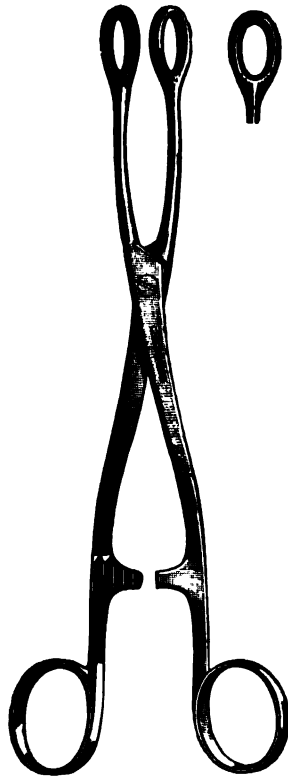


FIG. 13.—Tongue forceps.

as a general rule, when possible, that the dental prop should be placed not further forward than the premolars.

The mouth spoon (fig. 12), made for me by Messrs. Ash,

is safer than Mr. T. S. Carter's original pattern, in which the shank of the spoon is liable to separate from the bowl with obvious risk. By carrying the shank to the distal end of the bowl as in my pattern, this danger is obviated. The use of the oral spoon is to catch any teeth or roots which may fall out of the forceps. Lower premolars are especially apt to spring out of the beaks of the tooth forceps. The spoon is



FIG. 14.—Tongue forceps.

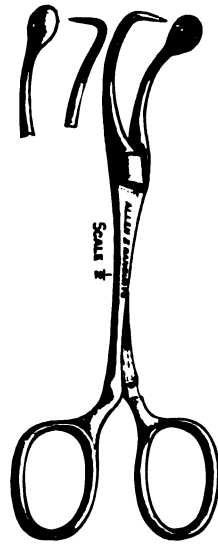


FIG. 14A.—Dr. Kingsford's tongue forceps.

held below the seat of operation, care being taken not to allow it to get in the way of the operator.

The **tongue forceps** (figs. 14 and 14A) need no special description. Some persons prefer to use an instrument which pierces the tongue, as the punctured wound is believed to heal

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PLATE II.



Pose of patient during the administration of nitrous oxide gas. The anæsthetist is placed behind in order to show the position of the patient and the face-piece. Normally he would use his left hand to hold the face-piece, not his right as shown in the figure, and he would stand on the left of the patient.

better than when the tongue is crushed. Dr. Kingsford's tongue forceps (fig. 14A) is the most convenient form.

A **tracheotomy case** containing sterilised instruments should always be at hand when an anæsthetic is to be administered.

It is important to have the apparatus ready for use and portable. The figure below shows a bag designed by me for this purpose. Props and instruments should be kept in metal cases, and face-pieces in metal holders.



FIG. 15.—Nitrous oxide case.

Administration of nitrous oxide for dental operations.—The posture of the patient is a matter of importance (see Plate II.). It is essential that he should be so placed that he is at perfect rest, his muscles relaxed and his breathing and circulation quite unimpeded. To achieve this he is seated in a chair, his body slightly extended on his pelvis, the legs hanging freely and not pressed against the foot-rest. When the legs are long the feet should touch the ground one on each side of the foot-rest. The head should now be in a line with the

trunk ; any marked degree of flexion or extension not only causes discomfort, but actually interferes with normal respiration. If the exigencies of the operation require any deviation from the natural pose of the head upon the shoulders, it is best for the anæsthetist to hold the head in the required position *after* the patient has become unconscious, and to restore it to its normal position as soon as possible. Thick-necked and stout persons should be most sedulously guarded against malposition as well as from the effects of pressure about the heart or the abdomen. Ladies suffering from slight goitre often disguise the deformity by a lace necktie. It is always wise in view of this to have such neckties undone, so that the anæsthetist may at once see whether any cervical swelling exists.*

The apparatus should be tested to see that the valves are working properly, and that the gas enters the bag freely ; the dental prop may be then placed in position. It must be carefully fixed in the opposite side of the mouth to that upon which the operation is to take place, and a glance cast round the mouth for artificial dentures, or an obturator, which, if present, must be removed. Weak or broken-down teeth should be noted and avoided in fixing the dental prop, and in the subsequent use of a gag. The administrator usually stands to the left of the chair, having the stand with the cylinders of nitrous oxide to his right and a little behind him. The gas bag should hang freely down to the left of the patient's chest. The patient is now to be reassured by a few cheering words, and directed to breathe naturally. It is well to allow a nervous subject to take several very deep inspirations before applying the face-piece, as these clear the lungs and divert the attention from a supposed horror of "taking gas." The Cattlin bag is partly filled by turning the toothed foot-piece under the foot from right to left. The gas must be allowed to leave the cylinder intermittently, as if permitted to flow

* A case in my practice emphasises this point. The patient was obviously a little breathless on entering the room, and to my question said she "suffered with her heart." The tachycardia suggested goitre, which was looked for and recognised, and measures taken to meet the exigencies of the case. The dental surgeon remarked to me afterwards that a death under nitrous oxide had occurred in his hospital, the patient being affected with goitre, which had been unnoticed.

continuously and rapidly it is liable to freeze and block the exit. The face-piece is then lightly applied to the patient's face, and retained by just sufficient pressure to prevent the escape of the nitrous oxide or the entrance of air around the air cushion. The face-piece should be held by the left hand of the anæsthetist in such a way that the thumb is placed across the mask above the attachment, the first finger parallel to the thumb should rest across the mask below the attachment, and the remaining fingers should support the patient's jaw, exerting a steady upward pressure of the face into the face-piece, while the forefinger and thumb steady the mask and maintain its due and accurate apposition to the face. Although no great force must be used it is essential that no air enters beneath the air cushion. This in-leakage is most apt to occur at the root of the nose and buccal regions, especially if the cheeks are hollow through loss of the normal buccal fat pads which should give the contour to the face. In a second or two, the patient becomes accustomed to the face-piece, and the administrator is able to learn that the valves act properly. At the instant of inspiration the stopcock is turned so that the patient inhales the nitrous oxide from the bag. During the administration this is kept nearly full of gas, by rotating the foot-piece from right to left. It is well to open the ingress way of gas during inspiration and close it during expiration.

After the first fifteen or twenty seconds, that is, after the lungs are presumably filled with nitrous oxide, and when gas is gaining tension in the blood, slight duskiness of the skin appears, the ears and finger-tips darken ; consciousness, however, is usually present for ten or fifteen seconds longer. In half a minute the patient's power of receiving impressions and reasoning upon them is greatly interfered with, and soon all consciousness is lost. At this stage, incautious acts, such as touching the conjunctiva, making loud noises, or roughly handling the patient, may lead to his completely regaining consciousness. In about forty-five seconds after the application of the face-piece, the pupils will usually dilate, the eyes becoming dull and expressionless, while squinting may occur. The conjunctival reflex will persist, and if the face-piece be removed now, the return to consciousness will be rapid.

There is at this stage, as a rule, time for the extraction of one tooth, if fairly loose. When the inhalation is not checked at this time and if no air is admitted, further signs of deeper narcosis appear. The breathing grows stertorous,* muscular movements of the hands and feet supervene, and the conjunctival reflex becomes sluggish, or disappears. The patient is now ready for operation, and it is not wise to attempt to push nitrous oxide beyond this point.

DEFINITE MIXTURES OF AIR AND NITROUS OXIDE.

Since a brief period of induction associated with violent movements of the body and limbs (jactitations) brings about a shortened period during which the operator can work, it is necessary to prolong the induction and prevent the movements. The actual period of anæsthesia varies in length directly as the amount of gas absorbed into the tissues, and in order to obtain the maximum nitrous oxide tension in the blood deprivation of oxygen (tissue asphyxia) must be prevented. When oxygen gas is not being employed with nitrous oxide in the manner described below, air may be admitted from time to time. If, for example, after a brief induction duskiness appears and the muscles about the eye begin to twitch, or jactitation of the limbs occurs the valve cutting off the gas is turned at the commencement of an expiration and air allowed to enter until one full inspiration is completed. The gas is then again admitted and this manœuvre repeated from time to time until a sufficiently deep narcosis is obtained. If too much air is given the anæsthesia will be brief and unsatisfactory. In some cases in which there is an initial cyanotic condition air must be used more freely or given continuously by allowing the air cut-off valve to remain slightly open.

Various methods have been suggested whereby the patient is given definite quantities of air and gas. That of Mr.

* Laryngeal stertor must be carefully discriminated from "snoring." Patients with a thick pendulous uvula, or enlarged tonsils or post-nasal adenoids, begin to snore a few seconds after the commencement of inhalation, also persons with loose baggy cheeks make a stertorous sound, but false stertor should be ignored. The true stertor, caused by vibration of the aryteno-epiglottidean folds, only comes on after forty or fifty seconds of inhalation, and is more musical in character.

Carter Braine* is simple and depends upon having an aperture in the face-piece controlled by a metal cap, the rotation of which admits air to the required amount, but the most exact is carried out by the apparatus shown in fig. 5 (p. 71). The principle involved in Mr. Coleman's† stopcock is that the entry of air and gas is made through apertures of equal size, while the amount of the former admitted depends upon the extent to which the air inlet is opened. The apertures are guarded by a single valve made of aluminium. The inrush of gas lifts this valve and so opens the air aperture simultaneously with the gas aperture; no air enters, however, unless the air inlet is purposely opened.

The advantage of this method over the one mentioned first is, that it is not necessary to shut off all gas when the admission of air is desired. The actual quantity of air let in will depend upon the requirements of each patient and upon the different periods of the induction, more being needed towards its close than would be necessary near its commencement.

The signs of unconsciousness which are most reliable are: the condition of respiration, which becomes automatic in type similar to the breathing during sleep, but more rapid; the expressionless eyes, which usually oscillate slowly; loss of conjunctival reflex, which may occur, but is by no means constant; and fine rhythmic stertor, with vibratory twitching of the orbicularis palpebrarum muscles. Lividity of the face is constant.

These signs, taken together, form a very definite picture, but experience will soon show the beginner that some of the signs are often difficult to detect and are easily overlooked. The breathing, the colour, and the look in the eyes form, in the absence of stertor and muscular twitching, the best guides. The length of time individuals take to become unconscious varies within wide limits. It is usually about a minute if air is allowed to enter fairly freely, but a longer time may be required. If this time is *much* exceeded and there is no obvious reason for the delay, such as a badly fitting mask allowing in-leakage of air, the tyro should lift the mask and make sure

* *Brit. Dent. Ass. Jour.*, April, 1895.

† *Proc. Roy. Soc. Med.*, Sect. Anæsth., Feb. 3, 1911.

that the patient's colour and breathing are satisfactory. When the anæsthetist is satisfied that full anæsthesia exists he signals to the operator by saying clearly and deliberately, "One—two—three," and then removes the mask, and the operation proceeds. During its continuance he must watch his patient's colour, and prevent foreign bodies—blood, and so on—from interfering with the breathing.

If any tooth falls into the mouth or any complication arises he should stop the operation at once, and take such steps as are called for to prevent danger to the patient. If a patient struggles it is usually better to cease the operation, and postpone it to another occasion, when precautions can be taken to avoid a repetition of the inconvenience.

SIGNS OF RECOVERY.

It is important to be able to recognise the signs of returning consciousness, so as to know when to desist from further operative measures, and this can usually be done with certainty. In the first place, the normal colour of the face returns, the lips change from their livid hue to a natural crimson. The eyes recover their look of intelligence. The patient commonly moves a limb, or utters a cry, though not one which implies consciousness; restless movements of the body often occur. Children, also, are very liable to cry out although quite unconscious, and it is well to warn friends of this, otherwise they may imagine the anæsthetic has failed.

It is claimed by some authorities that rebreathing the gas towards the end of the inhalation produces a more prolonged period of anæsthesia, and is in no sense prejudicial. To effect this rebreathing, the expiration valve is closed, and the bag becomes a "supplemental bag." It is difficult, even on theoretical grounds, to understand why the rebreathing of nitrous oxide should produce a prolonged effect, even if we admit that the supposed addition of carbon dioxide acts concurrently with the anæsthetic. As has been pointed out, the amount of this gas given off during the inhalation is lessened, so that the quantity acting during the few seconds occupied by the rebreathing would be extremely small. It is the devitalisation of rebreathed air, rather than its

impurities, as has been shown by Sir Benjamin Ward Richardson, which renders it deleterious. There is always *débris* from the lung tissue in rebreathed air, which, in many if not in all cases, it can hardly be desirable to breathe. In prolonged administration of this gas with oxygen, as practised by Dr. Teter and others in the United States, some degree of rebreathing is advocated, and the views on acapnia, which are so vigorously advanced by Dr. Yandell Henderson, would appear to indicate that the increase in the tension of carbon dioxide in the blood is by no means harmful. This statement does not, however, in any way invalidate the view the present writer takes that rebreathing, unless for a short time and after the lungs have been thoroughly washed out with nitrous oxide, is harmful in brief administrations and likely to produce after headache and malaise.

Occasionally the induction of anæsthesia by nitrous oxide is described in "degrees" of narcosis, but their delimitation is so slight and so empirical, that I have not adopted this plan.

The phenomena of the induction of anæsthesia by nitrous oxide varies in different types of persons, and these variations require special lines of management.

CONSIDERATION OF SPECIAL TYPES.

Muscular persons of powerful physique are often prone to struggle and fight. They are intolerant of restraint and appear to be peculiarly liable to dreams which excite them to movements while they are only partly "under" gas. They behave somewhat in the manner common in the early days when "nitrous oxide frolics" were in vogue. Too free access of air or oxygen in the early part of the induction increases the likelihood of struggling, while too rigorous exclusion of air (oxygen) in the later part leads to deep cyanosis and violent jactitation during complete anæsthesia. This is due no doubt to the hampering of respiration by the tonic contraction of the powerful musculature of the thorax and pectoral girdle. Great care must be taken in the adjustment of the patient's posture, the legs being astraddle on each side of the chair, while free ventilation with pure gas should be

permitted at the commencement of the inhalation. Before marked lividity or jactitation occurs, air (oxygen) should be admitted and the depth of inspiration be increased by lifting the mandible upwards and forwards. This will cause elevation of the larynx and so increase inspiratory effort. These patients usually require a considerable quantity of gas and the period of induction is commonly prolonged. Occasionally they become obstreperous as they resume consciousness.

Those of the **alcoholic** type are similar in their behaviour to those mentioned above. They, however, are curiously tolerant of this and all other anæsthetics. They lose consciousness or self-control, but are often difficult to guide into complete motorial quietude, and are prone to resume their semi-conscious violence after an inconveniently brief period of quiet. The anæsthetist has to remember that the confirmed toper is as a rule one whose tissues are fatty and diseased, and so, although it may be necessary to use some air exclusion and to force the anæsthetic, yet a real danger arises if any asphyxial complications are permitted to supervene during the nitrous oxide inhalation. Abstention from food for six hours, from alcohol and tobacco for some days before the administration, with purging, are useful preliminary measures, although the alcoholic are not easily advised in such matters. The blood pressure and condition of the arteries should be investigated in the case of persons over forty years of age. In both the muscular and the alcoholic it is most necessary to see that the face mask is fitting with absolute accuracy, as even a little in-leak of air will vitiate the result.

The **feeble**, **neurasthenic**, and **anæmic** present a problem in contrast to the above. They breathe feebly, are rapidly anæsthetised, but as quickly resume consciousness of pain. They are affected most deleteriously by air exclusion, being liable to syncope and respiratory cessation as well as to unpleasant or even dangerous after effects. The anæmic are peculiarly unfortunate in these respects. Happily, however, with care and judgment, the use of nitrous oxide when given with oxygen or air, the former being preferable, is seldom attended with alarming symptoms in these cases. The

guiding principles are a slow induction with free admission of oxygen, the nitrous oxide being more and more diluted until just before the mask is removed, when "charging up" with pure gas is desirable. Personally I refrain from permitting rebreathing in any of these cases, but some authorities advise it. A practical point is to make sure that full lung ventilation is taking place. During the first part of the inhalation these patients will inspire very feebly, and no sufficient tension of nitrous oxide can be achieved. They then doze and the breathing is still more shallow. Unless they are roused and encouraged to inspire, sometimes by pressing upon the jaw or compressing the thorax once or twice, they will hardly become fully anæsthetised. When once the automatic rhythm of respiration is started, this difficulty is at an end; until then the mere lapse of time must not be accepted as presumptive evidence of the advent of anæsthesia. I have known four minutes to be occupied by a patient before becoming anæsthetised by nitrous oxide when there was no reason save the psycho-physical one for so inordinately prolonged a period of induction. Nervous persons who have had anæsthetics repeatedly, and especially if they have suffered "painful experiences," often learn the trick of this ineffective breathing and require special treatment in the manner advised above. However, it is not safe to permit a very prolonged inhalation without watching the breathing closely. If measures to increase lung ventilation fail, the mask should be removed, for in some cases these patients will, by holding their breath, produce semi-asphyxia, and this with the nitrous oxide taken may cause grave danger to the circulation and respiration.

Children.—Even infants can take nitrous oxide, but it is not a good anæsthetic for those under six years of age. Unless a child has been frightened or is unruly through unwise training, it will inhale without trouble. Some nervous little ones become panic-stricken, and for these it is not kind to persist in argument beyond a certain time. If the operation has to be done and the parent recognises that some coercion must be used and agrees to it, it is best to hold the child firmly but gently, and after a few breaths of gas unconsciousness occurs and the child can be placed in

the proper position in the chair and the narcosis gradually deepened. Jactitations rapidly occur unless air (oxygen) is admitted; indeed it is essential to admit it or the period of anæsthesia will be useless for more than one tooth extraction. Children should always be made to urinate before inhaling, and should not take food for three hours anterior to the operation. They often cry out or sob during the extraction although insentient, and their friends should be warned of this. In very nervous persons and some children, the "open" method (figs. 16 and 17; see p. 89) is useful as a commencement of the induction, as the administrator can talk to them as if nothing was going on, and they do not perceive the gas is being taken. I think, as a rule, children should be taken into our confidence and everything explained. They should never be deceived and no attempt be made to use violence, the object of which they cannot understand and justly resent. The self-willed, spoilt child, however, compels some *force majeure* in his case, but its employment should be explained to him as due to his own recalcitrancy.

CONDITIONS OF RESPIRATORY EMBARRASSMENT.

The chief causes are—inflammatory swellings of the tonsils, fauces, tongue, and tissues of the neck adjacent to the larynx and trachea (Angina Ludovici), contraction of scars, *e.g.*, severe burns, glandular or other swellings, including œdema, so situated as to displace or compress the upper air passages; adhesions of the palate to the posterior pharyngeal wall, large masses of post-nasal adenoid growths, stenosis or occlusion of the nares; intra-thoracic conditions* due to acute or chronic disease, which either compress the trachea and bronchi or cause fluid to collect in the air passages; abdominal enlargement due to fat, fluid, gas, or growths interfering with the diaphragmatic respiratory excursion and incidentally

* In this connexion the persistence of an enlarged thymus gland must be remembered. This is commonly found in those who suffer from lymphatism. It cannot always be detected by percussion, but is said to cast a shadow when the neck is subjected to X-rays. Although definite evidence proves that a persistent lymus may press unduly upon the trachea, it does not always do so. Enlargement of the thyroid gland is often associated with a persistent thymus.

displacing the heart; general diseases, such as fevers, nephritis, cerebellar disease, bulbar disease, and so on, which either cause dyspnœa or bring about œdema; pleuritic adhesions are regarded by some as peculiarly dangerous.

In minor degrees of dyspnœa the use of oxygen with nitrous oxide, with sedulous avoidance of any added asphyxial condition, may render the use of nitrous oxide fairly safe, but when marked respiratory embarrassment exists, and in all inflammatory swellings involving the trachea, nitrous oxide is contra-indicated.

Circulatory impairment.—The special difficulties and dangers of giving nitrous oxide to patients who are the subjects of disease affecting the heart or vascular system or nervous mechanism controlling the circulation depend rather upon the results of the pathological condition than upon the actual lesion. The anæmic, the “overgrown” boy, the nervous sensitive child subject to fainting, persons with hypertrophied hearts, with high blood pressure associated with markedly rigid arteries, may be classed with “blue” patients whose cyanosis arises from congenital malformation, and constitute the most dangerous types of persons for anæsthesia by nitrous oxide. Syncope, rupture of a cerebral vessel, and asphyxia are the perils threatened in these cases, and if the conditions are at all marked it is probable that some other form of anæsthetic should be adopted. However, provided care is taken to avoid struggling or undue exclusion of air (oxygen) slight degrees of circulatory derangement do not contra-indicate nitrous oxide, they merely serve as indications of particular dangers and suggest the remedies, *i.e.*, free admission of oxygen or air and avoidance of all “pushing” of the anæsthetic.

General diseases have been referred to, and it now remains to point out that they only affect the patient through any tendency they may have to cause respiratory or circulatory embarrassment, and their treatment from the point of view of the anæsthetist is that indicated in dealing with these conditions. It is sometimes asked whether the so-called *status lymphaticus* constitutes an especial danger, and the answer is that such a condition, even if accurately diagnosed, is merely one denoting poor development and feebleness, and

although special care to avoid asphyxia and consequent heart strain is necessary, there is no serious danger in these cases.

Menstruation, pregnancy, and lactation.—If it is considered desirable to undertake an operation upon women during these times, nitrous oxide, provided cyanosis and jactitation are completely prevented, may be given. The foetus may be damaged by prolonged air exclusion, and violent muscular contractions may cause premature birth, but such complications should be prevented by the free admission of oxygen or air.

There will be rather more nervous prostration during lactation than occurs under normal conditions, and the first milk after the operation may be better rejected; otherwise no special anxiety attaches to these cases.

Children possessing slight lung ventilation and a small blood volume pass rapidly under "gas," and develop early muscular movements which are often very pronounced. The recovery is equally rapid, so that to secure a maximum period of quietude for operating little air exclusion must be practised. The gas and oxygen sequence is the best anæsthetic to use, and if air and nitrous oxide are relied upon, the greatest care must be taken by avoiding air limitation to prevent any suffocation or muscular movements. I have seen more than one cessation of respiration in young children which took place under nitrous oxide, but was at once remedied by gently compressing the chest.

The aged as a rule present no special difficulties; they are, however, intolerant of any asphyxial complication, and should such occur there is distinct danger of its causing faintness or even syncope. Air or oxygen should be given freely throughout, and every effort made to prevent the slightest blueness or muscular spasm.

AFTER EFFECTS.

These are, as a rule, conspicuous by their absence; hysterical women may laugh and cry, and work themselves up to a pitch of excitement, which sympathetic friends attribute to "the gas"; persons exhausted by fasting and

vigil or disease may become faint; epileptics occasionally have a fit during the exhibition of the gas, or immediately afterwards. Vomiting is rare after nitrous oxide gas, although such a complication may occur with children, or if the anæsthetic be given immediately after a meal. Pereira states that in one case loss of taste followed it, and I have met with a patient by whom anosmia was complained of for some days subsequently to the extraction of a tooth under nitrous oxide. Among a few persons of peculiar organisation, certain nervous symptoms have been known to follow, as for instance, severe headache and general malaise. Sleeplessness for a few nights occasionally occurs; I have met with it in a young delicate girl, who evinced no other ill-effect after inhaling nitrous oxide. Transient albuminuria has also followed it. It is alleged that glycosuria and even diabetes have been caused by the inhalation of nitrous oxide; personally, I have never known of any such complications. These symptoms, rare after a single administration, are less infrequent when this anæsthetic has been given twice at one sitting; hence it is better, when possible, to avoid the repetition. There is no doubt, I think, that patients who for some reason have become cyanosed, and whose respiration has become unduly laboured under the anæsthetic, are much more subject to these minor after effects than is the case with a normal uncomplicated administration. The graver dangers and deaths which have occurred under this anæsthetic are considered below (pp. 100, 122, *et seq.*).

Open method.—Certain persons and children are greatly alarmed by having a face-piece held over their nose and mouth. To obviate the necessity for this, Dr. Flux has devised an ingenious plan for giving nitrous oxide by an open inhaler.* His procedure is as follows:—Gas is poured into the upper open part of the inhaler through the stopcock leading from a gas bag connected in the usual manner to the source of supply. The nitrous oxide gas is only allowed to flow during inspiration, and owing to its greater weight falls directly into the face-piece. The movements of respiration, and the warmth of the expired vapour, tend to empty the

* See Dr. Flux's paper in *Transactions of the Society of Anaesthetists*, vol. ii., p. 140.

inhaler, to prevent stagnation of its contents, and to favour the mixing of gas with air. Violent injection of the gas into the face-piece is undesirable, especially in the case of small persons or shallow breathers, as the air by these means may be completely driven out before diffusion of the gas has had time to occur.

The inhaler is open at the top, and the edges must fit the face accurately in order to prevent any escape of gas below the level of the nose and mouth. With very young children

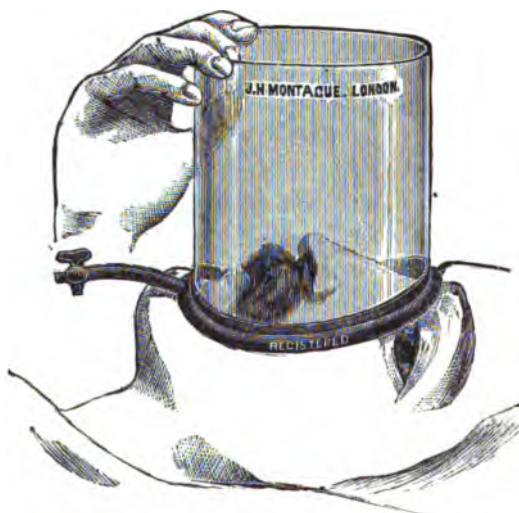


FIG. 16.—Flux's open method. Patient in recumbent position.

it is often convenient to use simply a folded napkin instead of a formal face-piece. In other cases, where it is inconvenient to employ a specially constructed open inhaler, an ordinary face-piece kept open by being tilted back from the face can be used. I have frequently adopted Dr. Flux's plan, and although recognising its merits in simple cases, I think it is better, when employing this method, to commence the inhalation by the open inhaler and conclude with the usual closed mask. In this way one avoids the initial fright and yet ensures a deeper narcosis and better anæsthesia than can be relied upon when the open mask is used throughout the administration.

PROLONGED ADMINISTRATION OF NITROUS OXIDE.

For cases where the operator requires an appreciably longer period for his work one or other of the following methods may be employed.

By mouth-tube.—Mr. S. A. Coxon's method* is as follows :—The patient is rendered unconscious by the use of the usual apparatus. The face-piece is then removed and a bent tube of large calibre connected with the nitrous oxide supply is introduced into the mouth so that its free end is a short distance from the uvula. It is most conveniently passed



FIG. 17.—Flux's open method. Patient in sitting posture.

behind the dental prop. A steady stream of nitrous oxide, which Mr. Coxon recommends should be warmed, is maintained until the operation is completed. Unless this warming is efficiently carried out the gas produces such cooling of the fauces as to cause undesirable results. The method has been now superseded by nasal methods.

Administration by nasal methods.—The use of nasal tubes and catheters for maintaining nitrous oxide anæsthesia was suggested by Mr. Alfred Coleman, who wrote to me

* *Transactions of the Society of Anaesthetists*, vol. i., p. 123.

about his plan some twenty years ago and subsequently made a simple apparatus * which I used for a time at the Dental (now Royal Dental) Hospital of London. Mr. H. Paterson altered the original pattern and used it with considerable success, but he and others found it possessed many drawbacks. Mr. Harvey Hilliard † has suggested an apparatus which in his hands appears to be successful. The plan consists in introducing a catheter through the nostril so that its free end hangs over the opening in the larynx. The nitrous oxide, as soon as anæsthesia has been induced by ordinary methods, is diverted and enters the air passages through the catheter.

Mr. Alfred Coleman's original plan of giving nitrous oxide by the use of a nasal cap has been recently improved by his son, Mr. Frank Coleman, by Mr. Trewby, and others.

In **Coleman's apparatus** the cylinders of gas are connected by tubing (RT) with a rubber bag (G) compressed by metal ribs (C). The upper exit of the bag is attached to a stopcock valve (ST-C) which allows nitrous oxide or air or a mixture of these gases to pass onward to the patient. The nose cap (NC) is made entirely of metal and is not easily displaced even when upper teeth are being extracted. It is provided with an expiratory valve (EV) and is fitted with lateral tubes of stout rubber (FT) which pass to the back of the patient's head and are held together by a sliding clamp (SC) which keeps the nose-piece in accurate apposition with the face without undue pressure. These tubes then pass down to the stopcock valve, completing the clear way from the gas supply to the patient. In some apparatus the mouth is covered by a metal mouth cap (MI) provided with an expiratory valve (EV) and the patient is instructed to inspire through his nose and expire through his mouth. Mr. Coleman has improved this by carrying a second gas tube (RT) from the stopcock to the mouth cap so that by depressing the metal handle (N₁OL) the gas enters both by way of the mouth and nose. When this is used it is immaterial whether the patient breathes by his mouth or by his nose. If the handle

* Subsequently described in 1898 before the Society of Anæsthetists; see *Transactions*, vol. i., p. 117.

† *Op. cit.*, vol. i., p. 170. See also *Dental Record*, April 1, 1898, p. 147.

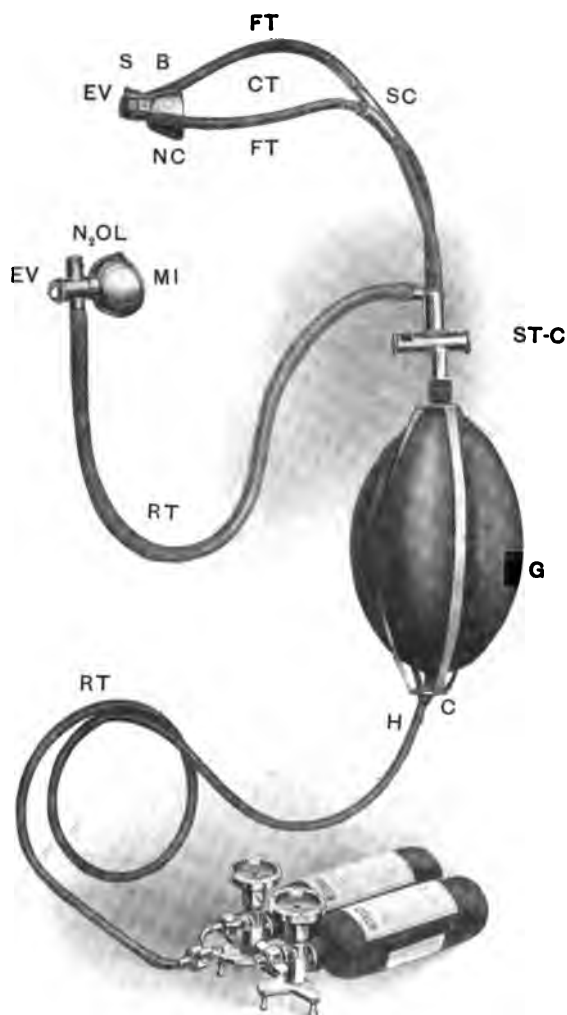


FIG. 18.—Mr. F. Coleman's combined mouth and nose nitrous oxide inhaler.

Combined mouth cover and inhaler—

MI—Mouth cover.
N₂OL—Nitrous oxide lever.

EV—Expiratory valve.
RT—Rubber tubing.

Nose-piece, etc.—

EV—Expiratory valve.
B—Body.
S—Shutter.
CT—Conveying tubes.
NC—Nose cap.
FT—Flexible tubes.

SC—Sliding clamp.
ST-C—Stopcock.
G—Gas bag distended.
C—Gas bag compressor distended.
H—Tubing to gas stand.

is allowed to escape, a spring causes it to rise and to close the gas supply to the mouth cover so that in that case the mouth cap acts merely as a means of expiration. The weight of the apparatus is supported by a chain and hook which can be attached to the operating-chair. When anæsthesia has been obtained the mouth cap and tube are dropped and the gas supply maintained through the nose. It is essential that the patient should have a fairly patent nasal passage and this fact should be ascertained before the inhalation is commenced. If there is much mucus in the naso-pharynx the patient should gargle freely with some mild astringent, Tinct. calendulæ and water, or Condyl's Fluid, a few drops being poured into tepid water flavoured with a little eau de Cologne.

The method.—The prop is fixed in position and the nose cap is then carefully adjusted while the patient is instructed how to breathe.

Then the mouth cap is put over the mouth, care being taken that no air can enter between it and the sagging cheeks or below the nasal cap. If the expiratory valve responds well to the patient's breathing the stopcock is arranged so that gas enters both by the mouth and nose. The lever (N₂OL) is depressed to admit gas to the face-piece. The gas supply to mask and nasal cap is controlled by the sliding valve (ST-C). The clamp (SC) slides along the tubes and fixes them in position as is seen in Plate III. If the expiratory valve does not act well the patient must be encouraged to "blow out hard" when the valve will evidence the success of his effort. The signs of anæsthesia are those mentioned in the preceding sections. Its onset is about as rapid as by ordinary oro-nasal methods. There is, however, a greater liability to the supervention of cyanosis and this must be obviated by moving the stopcock so as to admit air or by opening the expiratory valve in the nasal cap.

Provided that the patient breathes well it is possible to maintain anæsthesia sufficiently long for the performance of any dental operation. If the narcosis becomes too light and movement occurs, the mouth cap is re-applied, after sponging out any blood which is in the mouth, and the patient is put more deeply under the influence of the gas. Great care must be taken to avoid cyanosis. The recovery is less rapid than

PLATE III.



Shows Mr. Coleman's combined mouth and nasal administration of nitrous oxide. The administrator would usually stand to the left of the chair and the bag would hang behind it. Note method of holding the inhaler and arrangement of tubes and clamp.

in the case of ordinary methods, and the patient is apt to be dazed and sometimes complains of being "done up" after a prolonged inhalation.

Mr. Trewby's apparatus* is somewhat upon the same lines, but possesses many features of excellence which commend it. The figure (fig. 19) depicts its salient points so that detailed description is unnecessary. The method of use is the same as that of Mr. Coleman's apparatus.



FIG. 19.—Mr. Trewby's nitrous oxide oro-nasal inhaler.

A considerable supply of nitrous oxide must be at hand, as 50 to 80 gallons may be required for a ten minutes' anæsthesia, although experience with the use of the method enables an administrator to lessen very considerably the amount of anæsthetic expended for each patient.

Mr. Lennox, of Cambridge, has suggested a very simple and efficient apparatus for nasal anæsthetisation. This is figured

* See *Proc. Roy. Soc. Med.*, 1911, vol. iv., pt. 1., p. 12.

below. As is shown, the nasal cap fits closely to the nostrils and does not get in the way of the operator; this device is most useful when the patient is short lipped, or when anterior upper teeth have to be removed.

Experience has convinced me and others that valuable as are nasal methods, yet they are not so safe as mouth methods and should only be employed in picked cases, and for patients whose physical condition seems such as to render the strain



FIG. 20.— Inside and outside views of Mr. Lennox's nasal anæsthetiser.

imposed upon both the heart and the respiratory system a matter of no serious risk to them.

IN MAJOR SURGERY.

Although various attempts were made to use nitrous oxide for prolonged operations, and successful cases of ovariectomy, ablation of the breast and other major operations have been recorded from early in the career of this anæsthetic, yet no serious and systematic attempt to utilise it for prolonged anæsthesia was made until within the last ten years, and only then when it is employed with dilution by oxygen. Mainly at the instance of Dr. Crile and through the enthusiasm and enterprise of Dr. Teter of Cleveland, Ohio, has this come about. The subject is dealt with fully at page 114.

DIFFICULTIES AND MINOR COMPLICATIONS UNDER NITROUS OXIDE.

Retching and vomiting.—Some persons retch as soon as the mouth is fixed open by the dental prop, and actual vomiting may ensue. In most cases this arises from the mouth having been too widely opened, and can be corrected by bringing the prop forward and letting the mouth be partially closed. It is occasionally necessary to employ an extremely small prop and open the mouth by means of a gag when the patient is unconscious. In extreme cases, if the patient gargles the throat, or has it lightly sprayed with a solution of cocaine (2%), the trouble can be overcome.

Vomiting is especially liable to occur if the patient is permitted to swallow blood and mucus, so that when multiple operations are done, a sponge secured by a string should be placed over the oozing sockets as soon as the extractions are completed.

More troublesome patients are those who commence to retch at a point when unconsciousness has occurred but the narcosis is only light. It is usually impossible to push the nitrous oxide inhalation, and one has to be content with a brief anæsthesia, or adopt another anæsthetic. I have more than once met with patients, dyspeptics, who "belch" as soon as the prop is applied and then retch and complain of great distress. It is necessary in extreme cases to give gas, either nasally without a dental prop, inserting one when the patient is unconscious, or to anæsthetise, insert a prop, and then re-anæsthetise. Probably the former method is the better one.

Holding the breath by nervous patients can usually be overcome by the anæsthetist's tact and a few encouraging words, but I have met with persons who have induced semi-asphyxia and faintness by their persistence in breath-holding. Pushing the jaw forward rhythmically will induce an inspiration, and breathing once started will be maintained. Force should never be used except when it is necessary to prevent the patient from hurting himself. Children may be restrained, however, and compelled to inhale provided their parents

are willing that a certain amount of firmness should be employed. In every case of breath-holding it is essential that one should ascertain whether any physical reason for it exists, such as spasm of the larynx or faulty position of the patient.

Coughing, sneezing, and "gagging" seldom give trouble except in the stout and plethoric. If there is reason to fear the result of straining, as when the heart is feeble, it is better to give oxygen freely, or failing this, air, and not to press the anæsthetic until the complication has passed off. If the condition occurs early and obviously produces great distress, it is better to take off the face-piece and start *de novo* when the patient has got over the attack. "Gagging" is usually due to irritability of the pharyngeal wall and commonly occurs in smokers. In slight degrees it is remedied by pushing the anæsthetic. If the condition is known to be present a preliminary gargle and spraying of the throat with 2 % cocaine solution are useful.

Pallor and cyanosis.—Paling in young patients may arise from slight faintness, but must be closely watched, as if it increases, especially when nitrous oxide is being given by itself, it may lead to syncope and require prompt treatment, such as lowering the head. Cyanosis on the other hand is commonly met with among elderly persons, especially if stout and plethoric. It increases even after the withdrawal of the face-piece, and requires careful treatment. Even with oxygen this condition may supervene, and if in spite of increasing the oxygen it is not removed, the patient should be allowed to come round, as forcing nitrous oxide in these cases is a dangerous practice.

Hæmatemesis and epistaxis.—The former rarely occurs, and when it does must be treated on general medical principles. It is obviously essential to place the patient in a recumbent posture and to turn the head to one side. But like epistaxis, a minor degree of hæmatemesis may occur, and not be recognised if the administrator has allowed his attention to flag. Epistaxis will seriously interfere with respiration when the head is extended. Slight nose bleeding is not at all uncommon after inhaling nitrous oxide; it is most common

among young persons. In either case, the administration must be stopped as there is danger of blood trickling into the air passages or clotting over the rima glottidis, thus interfering with respiration.

Hysteria and excitement. — Occasionally excitement, almost maniacal, occurs after nitrous oxide, while lesser degrees of emotional disturbance are not uncommon. No serious treatment is necessary; judgment and firmness will meet the requirements of the case. The tendency to erotic dreams and hallucinations under these circumstances should be remembered and steps taken to prevent displacement of clothing and sliding of the body out of the chair. The liability in the case of women to believe they have been assaulted while unconscious enforces the necessity of avoiding being left alone with a patient under such circumstances.

Dislocation of the jaw, either partial or complete, may occur. The relative position of the teeth in the maxilla and mandible should be noticed as soon as the dental prop is removed, and if the jaws cannot be closed prompt measures must be adopted to reduce the subluxation, if possible before the patient is fully conscious. Patients often volunteer the statement that their jaws "are very loose, and slip out," and this warning should cause care to be taken to support the mandible and to avoid an unduly wide separation of the jaws by the dental prop and gag. Its treatment is usually simple. Standing in front of the patient, the surgeon protects his thumbs with two cloths wrapped round them. He places his thumbs as far back as possible on each side in the molar regions, and exercises steady but firm pressure downwards and backwards, while, with his fingers grasping the mandible, he lifts this up and so slides the displaced condyles back into their sockets. In returning, the muscles snap the jaws together, and unless the thumbs are properly protected they will be severely bitten. Incomplete dislocation is the commonest accident and is generally reduced with ease. Bruising of the tongue, lips, or gums with forceps or gags, or burning with carbolic acid, can only result from carelessness, but their possibility should be kept in mind. The same applies to breaking or displacing teeth when introducing a

gag. Usually if the tooth is replaced in its socket it will get firm again in time.

DANGERS ATTENDING NITROUS OXIDE ADMINISTRATION.

Respiratory difficulties.—In some cases, a certain amount of laryngeal spasm may occur, although it is rare. A case has been reported in which this condition was so severe as to render laryngotomy necessary.* As a rule, drawing forward the tongue, using rhythmic traction, will relax the spasm. Breathing in some cases becomes very shallow and may stop altogether, but this need not cause alarm unless indeed it should cease for longer than five or six seconds. Then it is well, after seeing that there is no falling back of the tongue or foreign body impeding respiration, to press up the ribs from below by standing in front of the patient, and grasping the chest with both hands placed about the lower half of the bony thorax. This simple manœuvre will initiate spontaneous respirations, and all will go well. Young children occasionally cease to breathe if the nitrous oxide is pushed to profound narcosis, and compression of the chest becomes necessary. Patients suffering from conditions such as laryngeal stenosis, goitre, enlarged glands, and inflammatory swelling of the neck are peculiarly liable to respiratory difficulty under nitrous oxide. As has been pointed out, it is better to avoid this anæsthetic for such cases, and if it is used at all it must be limited in dose, and all asphyxial phenomena carefully

* This instructive case is published by Sir F. Hewitt. A patient, æt. 35, suffered from fixation of the bodies of the vertebræ which precluded all save very slight rotatory and nutatory movements. The neck muscles were unduly rigid and the jaws could be opened only to a fourth of the normal extent. The fixation was the result of rheumatic fever. The gas was taken well and the tooth extracted. It was then remarked that the usual recovery did not occur, the respiration becoming more and more embarrassed "as though some obstructive condition of the air passages" existed. "The sound made by the last attempt at respiration was to a certain extent suggestive of fluid at the back of the throat." General fixation of the thoracic walls and rigidity of the jaws and vertebræ as well as of muscles of the neck rendered the measures usually adopted, such as artificial respiration, swabbing out the pharynx, etc., impossible; and as inversion failed to restore the patient's respiration, Sir F. Hewitt performed laryngotomy, which at once relieved the spasm, and the patient did well. See "Anæsthetics," 4th ed., 1912, pp. 564-5.

watched for and remedied by the use of oxygen, and the upper air passages must be opened if death from asphyxia is imminent. Even enlarged tonsils, especially when inflamed, may cause serious danger under this anæsthetic. A case in which death followed the administration has been recorded * (see p. 122, Case I.). I have on a few occasions met with respiratory difficulty which was fortunately only transient, evinced by cyanosis and severe dyspnœa in persons whose only apparent disability consisted in their being plethoric, and having a short thick neck and rigid chest.

Asphyxia caused by foreign bodies.—Vomiting during inhalation of nitrous oxide is uncommon, but may occur and even escape notice. If the vomit is aspirated into the lungs fatal results may follow, especially if the patient has incautiously taken solid food recently. Portions of undigested meat or other solid may, of course, become impacted in the glottis and cause dangerous or fatal results. Impaction of masses in the œsophagus may by pressure produce suffocation. A sponge used to prevent blood entering the larynx has in one case proved fatal. The person who placed the sponge in position appears to have forgotten it, and it was allowed to remain over the glottis occluding the air passage while artificial respiration was kept up. Among dangers must be mentioned those which are due to the operation rather than to the anæsthetic. Thus, a prop placed between the teeth may slip back into the windpipe if not secured to another hanging freely outside the mouth. Accidents have arisen through breaking of corks or dental props so that the latter should be made of some material not liable to crack or break off. The mouth must be cleared of artificial dentures, especially small plates. Accidents have occurred from teeth or portions of teeth being allowed to fall back from the beaks of forceps to the glottis, and thence entering the trachea. Premolar teeth from their shape are very prone to jump out of the forceps during extraction (Case B, p. 125). In several recorded cases these teeth have entered the trachea and caused death, either at once or secondarily, by causing abscess of the lung. The tooth forceps themselves have broken, and a fragment become lodged in the bifurcation of the trachea.

* *Transactions of the Society of Anaesthetists*, vol. vi., p. 12.

The dangers of these casualties are :—(1) immediate, from asphyxia due to laryngeal spasm excited by the foreign body becoming impacted in the larynx ; and (2) secondarily from septic pneumonia set up by the foreign body having found its way into a bronchus.

To deal with such cases.—Firstly, as to precautions. All instruments used for the mouth should be carefully examined for flaws, and all gags, props, etc., and secured by fishing-gut, or some strong cleanly material, and attached outside the mouth.

In extracting teeth the forceps should after each extraction be wiped quickly *twice* across a napkin, in order to free them from the tooth just removed before the next extraction is attempted. Fragments of teeth should never be left loose in the mouth, even with the object of gaining time. The use of the mouth spoon (p. 75) will often avoid these serious accidents.

Should there be any fragments detached from the tooth or forceps, etc., which cannot be seen and picked out, the anæsthetist should at once bend the head forward and sweep the finger round the mouth so as to carry any foreign body forward, where it can be seized and removed ; in this way it may sometimes be possible to dislodge a foreign body lying near to the epiglottis. It should be remembered that the tongue must not be drawn forward, as by doing this the larynx will be left exposed, the epiglottis being dragged from it, also because the patient is thereby induced to take a deep inspiration which facilitates the passage of the foreign body into the air passages.

If the obstruction cannot be felt, and there are signs of impending asphyxia, inversion should be attempted, and the patient if sufficiently conscious should be instructed to breathe out very deeply, coughing with the act, while he inspires as shallowly as he can. This manœuvre has succeeded in dislodging a tooth which had passed into the trachea. There is, however, a danger that inversion may cause the foreign body to lodge in the larynx and so excite spasm, and should this occur the trachea must be at once opened.

Failing all other measures, if the patient be dyspnœic and

death by asphyxia seems imminent, the trachea must be opened by tracheotomy* (see Chapter X.). When the asphyxial symptoms are due to the patient having vomited into the face-piece, it will usually suffice to forcibly open the mouth, if not already open, and sponge away the vomitus. However, solid food may become impacted in the rima or œsophagus occluding the larynx by pressure, and so necessitate the opening of the trachea below the obstruction.

Syncope.—Among the graver complications may be noted syncope. While syncope seldom occurs during nitrous oxide narcosis, it is undoubtedly a possible danger, especially among the neurasthenic and feeble, and in the case of elderly people who are fatigued or have come upstairs rapidly. It may take place before complete narcosis, and is then probably due in part to subjective sensations, such as dread of the impending operation, terror of the anæsthetic, or fear of suffocation. There are reported cases in which syncope has only been observed after removal of the face-piece, while in others all has apparently gone well until the operation has been commenced, when the condition of the patient suddenly became alarming. Whether death from syncope due wholly and solely to nitrous oxide has ever taken place is doubtful. In the few deaths which have attended the use of nitrous oxide, and have been reported, incomplete anæsthesia has played an important part, while fright and shock have undoubtedly contributed to the causation of the fatal result. When this anæsthetic is given without regard to the avoidance of asphyxial complications it may lead to syncope, due to grave interference with the pulmonary circulation. Persons whose breathing is hampered at the time of taking nitrous oxide incur the gravest danger of syncope, if this gas is incautiously employed. The anæmic are also liable to this danger, unless care is taken to avoid undue deprivation of oxygen. Stout women wearing tightly laced corsets are prone to syncope, and have succumbed to this while under the influence of nitrous oxide, especially when the stomach was distended by a recent meal.

* The operation of laryngotomy which some authorities recommend in these cases is less effectual.

Faintness.—Less severe forms of circulatory failure may, however, sometimes supervene, such as faintness, and these should be counteracted by placing the patient supine on the ground, chafing the hands, applying smelling salts or aromatic vinegar to the nostrils, and slapping the face and chest with towels wrung out in very cold water. All garments about the waist, chest, and neck, must be loosened, if this has not been done, as it should have been, before the gas was administered. The inhalation of a few whiffs of nitrite of amyl will often relieve the heart. It is sometimes advised to inject ether under the skin, but the utility of this is doubtful, nor is it likely to be called for in the class of cases above mentioned. A measure which I have practically tested and have every reason to estimate very highly is partial or total inversion of the patient. In the movable dental chairs so commonly used, this can be done even in the case of women without indelicacy or difficulty. In minor degrees of faintness such as often supervene after an extraction, bending the body down so that the face is placed between the patient's knees will expedite recovery. A few inhalations of oxygen will often greatly assist such persons and raise blood pressure. Such transient faintness is commonly the result of nausea, or may even herald vomiting. It must always be borne in mind when giving nitrous oxide to a stranger that he may be the subject of cardiac disease or angina pectoris, and may not associate any danger with this condition even if he knows of its existence. Some slight emotional disturbance, fatigue or oppression due to a walk in sultry weather is enough, when added to some respiratory embarrassment due to the anæsthetic, to precipitate serious or even fatal consequences (see Case VI., p. 124).

Mania is a rare complication following nitrous oxide inhalation, which has occurred in persons subject to mental disease.

Epileptic fits may occur during the induction or following anæsthesia, but beyond taking care that the tongue is not bitten no special treatment is necessary.

Hemiplegia and apoplectic seizures have been recorded as occurring after nitrous oxide, but are extremely rare (see Case A, p. 125). When there have been much straining and

cyanosis, ocular ecchymosis and even retinal hæmorrhage may result after this anæsthetic.

THE USE OF NITROUS OXIDE IN THE PUERPERIUM AND IN DISEASE.

Pregnant women, provided they be not within a very short period of their accouchement, are not prejudicially affected by this anæsthetic. The shock of even a minor operation is quite as likely to provoke premature delivery as taking nitrous oxide. The child appears also to be quite unaffected, as one would expect, since its oxygen tension is habitually low, and further because the elimination of nitrous oxide from the blood is very rapid. Especial care should be taken in administering nitrous oxide in these cases and all asphyxial complications must be avoided, as the nervous system is peculiarly liable under such conditions to receive strong impressions and is easily thrown off its balance. Hysterical emotional outbursts if they occur will certainly be attributed to the inhalation, so that unless imperatively called for, operative measures should be deferred until after parturition. In the early months of pregnancy vomiting may be excited by nitrous oxide.

Lactation is not in the majority of cases prejudicially affected by nitrous oxide gas. During menstruation women may safely take this anæsthetic, with the reservation that since their nervous system is at this time less stable than ordinary, these patients will be a little more likely to be "upset," hysterical, and so on. It is noticed elsewhere that erotic hallucinations under nitrous oxide are more prone to occur at the "monthly period" than at other times.

Advanced age, as such, offers no reason for declining to administer nitrous oxide, patients over ninety having taken it successfully. When great **vascular feebleness** exists, there is more risk, as the greater tax imposed upon the heart by checking oxidation in the lungs, and so impoverishing the tissues, may provoke syncope. However, with due care and watchfulness, even the very feeblest can take nitrous oxide with impunity. In practice

I have found it wise to administer a little ether in conjunction with the gas when great circulatory enfeeblement is present.

In extensive lung disease, especially in phthisis, when hæmorrhage has been known to have occurred, nitrous oxide must be given with caution, as there is danger of exciting fresh bleeding from the lungs. According to Mr. Woodhouse Braine, narcosis deepens in phthisical patients after the withdrawal of the face-piece, and so special care is needed in the management of such cases. It is probable that this is really due to enfeebled expiration preventing the usual elimination of the anæsthetic.

Heart disease, except when the tendency to syncope is considerably increased, is no contra-indication to giving nitrous oxide. In all cases it is necessary to weigh in one's mind which will be more likely to jeopardise the patient's welfare—the performance of an operation without an anæsthetic, or the giving of the anæsthetic. Broadly it may be stated that if the patient can support the shock of the operation, he will certainly survive the anæsthetic. **Valvular disease**, unless marked want of compensation is present, is not contra-indicatory to nitrous oxide inhalation. When the heart is greatly dilated and the hypertrophy has failed to overcome the obstructed circulation, or when marked muscular degeneration of the heart fibres has taken place, there is necessity for caution, and of such patients the most anxious care should be taken. In all the cases referred to in this section it is best to employ nitrous oxide and oxygen, or air, rather than to rely upon nitrous oxide by itself.

DEATHS FROM NITROUS OXIDE ADMINISTRATION.

Several deaths have been imputed to the use of this agent, but it is doubtful whether any of the cases recorded were directly due to the physiological action of nitrous oxide gas. In some instances insufficient narcosis was maintained, and as a result the patient *felt the pain*, and syncope ensued. In others, either the entire gag or a portion of it slipped, and found its way into the patient's

larynx, there to excite spasm and suffocation. A fuller account of these fatalities will be given at the end of this chapter.

NITROUS OXIDE GAS WITH OXYGEN.

The apparatus devised by M. Fontaine for carrying out Paul Bert's method of giving these gases under pressure, has practically gone out of use, so a mere mention of it will suffice. The name of Paul Bert must, however, always be remembered with honour in this connexion, for his classical researches (*Compt. rend. de l'Acad. des Sc.*, 1878, 1879, etc.) paved the way for the present simpler and better methods.

Dr. Hillischer was one of the first to point out the value of associating oxygen with nitrous oxide. He called the mixture *schlafgas*, and in a pamphlet under this caption advanced his reasons for its use and described his apparatus contrived for their exhibition.

This apparatus I have used, but have not found it so satisfactory as more recent inventions. The inhaler commonly used in this country is that of Sir Frederic Hewitt.*

The apparatus.—Two bags completely separated by an indiarubber division contain the two gases. The employment of separate bags has one advantage, viz. that if one bag is distended it does not exert pressure upon the second bag and so defeat the object the administrator may have in view, that namely of producing a plus pressure of one or the other gases which he is employing. These are severally connected by tubes arranged one within the other with the steel cylinders containing the oxygen and nitrous oxide respectively. The oxygen passes into a small chamber which is separated from the mixing chamber, but can escape into the latter by one or more perforations in the wall when the revolving inner drum is turned. This is moved by a handle attached to the indicator. The figure given below shows the apparatus complete (fig. 21), and the various portions of the regulating stopcock with the mixing chamber are seen in fig. 22, p. 109. Fig. 22 shows in detail the arrangement of the mixing chamber and the working

* These figures of his apparatus are lent me by Sir F. Hewitt, and appear in his book, "The Administration of Nitrous Oxide and Oxygen for Dental Operations," Claudius Ash and Sons, London.

of the various valves. As success in the use of this apparatus depends upon these being in order, it is wise for the anæsthetist to separate the parts periodically and inspect the condition of the valves so as to see whether they are in their correct



FIG. 21.—Sir F. Hewitt's apparatus for giving nitrous oxide gas with oxygen.

position and whether the rubber of which they are composed has perished and needs renewal. If this is not done the gases may pass back into the bags and become mixed, and even if a valve sticks, the supply may be cut off and failure may ensue,

causing distress to the patient and chagrin to the anæsthetist. A supplementary stopcock can be fitted which enables the administrator to increase the supply of oxygen to meet any emergency.

The most careful attention to carrying out its details is essential for this method. The utmost accuracy in fitting the

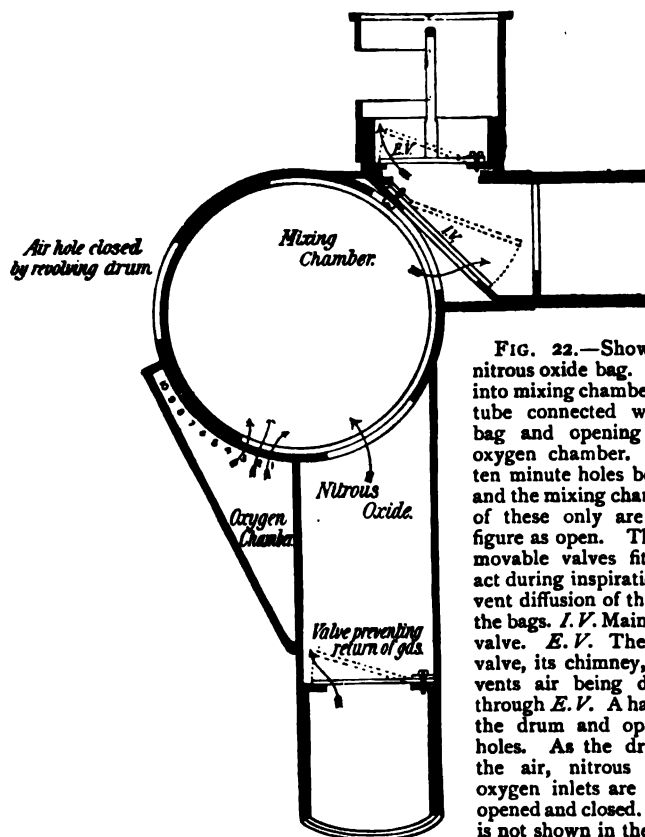


FIG. 22.—Shows tube to nitrous oxide bag. Its opening into mixing chamber. Oxygen tube connected with oxygen bag and opening into little oxygen chamber. There are ten minute holes between this and the mixing chamber; three of these only are shown in figure as open. There are removable valves fitted, which act during inspiration and prevent diffusion of the gases into the bags. *I.V.* Main inspiratory valve. *E.V.* The expiratory valve, its chimney, which prevents air being drawn back through *E.V.* A handle rotates the drum and opens oxygen holes. As the drum rotates, the air, nitrous oxide, and oxygen inlets are respectively opened and closed. The drum is not shown in the figure.

mask, and excluding the entrance of air beneath the air cushion are essential. It is well also to make oneself quite sure that the terminals, *i.e.*, the N_2O and O_2 , are attached to the appropriate bags. The metal collars should have the above letters impressed or scratched upon them to avoid possible mistakes.

The patient should be made breathe two or three times through the apparatus (fig. 21) to ascertain that the valves are working, or better the anæsthetist should himself test them before applying the mask. The handle attached to the indicator is then to be turned so that the latter points to "2," thus permitting a small quantity of oxygen to mix with the nitrous oxide. If the patient is a child, is anæmic, or shows signs of rapidly developing cyanosis it is well to push the indicator at once to "4." After a few breaths, should any duskiess appear, the indicator should be pushed to "5" and "6" or onward as the judgment of the administrator suggests. The appearance of signs of cyanosis, stertor, muscular twitchings, are indications for allowing more and more oxygen to enter the mixing chamber, while the presence of a ruddy red flush over the forehead, an apnœic condition without blueness, the commencement of purposeful muscular movements, signs of excitement, talking, persistent consciousness, are indications that the patient is getting too much oxygen. In this case the indicator can be turned back to "2" or even " N_2O " until quietude is established. At this stage it is well to again allow some oxygen to enter, and if the patient takes this percentage with success, to allow him to inhale for a minute or so after anæsthesia has developed itself. In this way a more prolonged period of anæsthesia is obtained. This will be necessary when the apparatus is used for prolonged anæsthesia. Sir F. Hewitt prefers to have the bags only partly distended and insists upon the importance of maintaining them as nearly as possible of the same size throughout the administration. If, however, the symptoms are carefully watched I think perhaps the best results are obtained by keeping the oxygen bag about half full, and by varying the fulness of the nitrous oxide bag as the symptoms seem to demand. It must, however, be remembered that filling the one bag exerts pressure upon its companion through the dividing septum, and hence neither bag should ever be filled to distention. The possibility of a small opening between the bags should be borne in mind if anomalous symptoms caused by an excess of oxygen in the mixture become apparent. At the point when the patient is anæsthetised it is my custom to discontinue the supply of either gas from the cylinders and to

allow the patient to breathe the mixed gases without any added pressure from the inrush of a fresh supply. A somewhat similar inhaler has been devised by Mr. Wellings. It possesses an advantage over the one just described in that the supply of oxygen is regulated by wedge-shaped slots such as are used in carburetters instead of by a series of round apertures. This provides a more even and reliable flow of the gases and is more easily cleansed. I have used this inhaler and find it most satisfactory.

The inhalation will occupy in many cases two minutes or even longer.* Indeed, the longer the period of induction is, provided too much oxygen has not been admitted, the more satisfactory will be the anæsthesia. The **signs of anæsthesia** are soft "distant" snoring breathing, fixation of the ocular globes and usually an insensitve conjunctiva. The muscular system should be fully relaxed. The pupils usually remain of normal size. The **period of anæsthesia** varies within wide limits but is usually slightly longer than when nitrous oxide is given alone. **After effects** such as **languor, nausea, vomiting, headache, slight vertigo**, which follow the use of nitrous oxide diluted with oxygen, are slightly more frequent than is the case when nitrous oxide is used alone. This is probably due in part or entirely to the more prolonged period of the induction of anæsthesia. The patients are longer in recovering their wits and occasionally remain in a dazed state for some minutes. The **after effects** following the use of nitrous oxide and air are practically those already described in speaking of nitrous oxide. In the case of nitrous oxide when used with oxygen, the only after symptom of any moment is that of nausea with or without vomiting. This is rather more frequent as a complication when this mixture is employed than when nitrous oxide is given alone. On the other hand, the evil effects of cyanosis and its sequelæ are conspicuously absent after nitrous oxide and oxygen. No case of death which can be regarded as being the direct result of this mixture when employed for brief operations has been reported, so that we must regard the method as extremely safe.

Cases VI., a death, p. 124; also A, B, and H, pp. 125 and 127, reveal the fact that certain well-marked dangers may arise

* Sir F. Hewitt gives his average as 110 seconds.

even when this mixture is employed. As is pointed out below, the claim for safety of nitrous oxide and oxygen as an anæsthetic in brief operations is not as certainly true when it is employed for prolonged operations in major surgery.

Experience alone can enable the administrator to regulate the amount of oxygen required for any given case. It should be remembered that the addition of oxygen is simply made to enable a patient to go on breathing nitrous oxide without suffering from oxygen starvation. In other words oxygen is an adjunct and not an adjuvant anæsthetic such as is ether, so that as little should be given as is consistent with maintaining the required oxygen tension in the pulmonary air cells. Thus **full-blooded men** in robust health require less oxygen, **alcoholic subjects** are apt to become excited if oxygen is given at all freely at first. **Children**, the **anæmic**, and persons in **feeble health**, or who suffer from any disease giving rise to **cyanosis** and **venous engorgement**, especially where the **circulation is feeble**, require more oxygen, and frequently the quantity given must be rapidly increased at the commencement of inhalation, even if the amount is lessened later on. It should be remembered that when a slight excess of oxygen is given the patient is apt to pass into a state of passivity; although unable or reluctant to move, he yet may cry out and experience painful sensations during the operation; in this case the anæsthesia is really incomplete and extremely transient.

After effects of nitrous oxide with oxygen.—These are the same as those already mentioned as occurred with nitrous oxide. There is more likelihood of prolonged dazing of the senses, of nausea and vomiting with this combination, and Mr. Edgar Willett has met with prolonged torpor, lasting four days. Sir. F. Hewitt records cases of maniacal excitement, but there seems no sufficient evidence to associate such very rare sequelæ causally with the use of nitrous oxide and oxygen. The cases cited below (pp. 122–130) give some interesting examples of the possible dangers of this method and deserve very careful study. There is a real danger threatening its use by those not familiar with it, that, since the signs of anæsthesia are not always easy to recognise, they may be tempted to prolong the administration to a dangerous length.

Nitrous oxide in combination with ether.—In cases in which more time is required than nitrous oxide gives, the use of ether—but in conjunction with the gas—is to be recommended. The apparatus which I have found most serviceable is what was called Clover's gas and ether inhaler, although since Mr. Clover's time many useful alterations have been made in its construction. The reader is referred to page 170 for particulars of this method.

Nitrous oxide and chloroform.—Although many persons have attempted to establish this succession and some have used the combined vapours, the writer is convinced that either method is dangerous, while the first is open to the objection that unless the nitrous oxide is kept up *pari passu* with the chloroform inhalation the patient comes round from its effects before those of the chloroform have declared themselves. (See Case of Death No. III., p. 123.)

Nitrous oxide in combination with ethyl chloride.—The employment of nitrous oxide antecedently to ethyl chloride is described in dealing with ethyl chloride, and the reader is referred to that section.

Nitrous oxide given from a gas-container.—Where a gas-container is kept, a modification of the above apparatus is in use. A long tube screws on to the efferent pipe of the gas-holder conveying the gas to a bag of 2 or 3 gallons' capacity. This may be connected directly with a face-piece or conveyed to it by another length of tubing, and by using a three-way cock it is easy to combine this apparatus in gear with Clover's small ether inhaler, or with apparatus figured on page 151.

Prolonged nitrous oxide administration.—In cases in which the surgeon requires access to the mouth, nitrous oxide may be administered through the nose, as described above (p. 91). The only difficulty in the management of these cases is, avoiding on the one hand cyanosis, and on the other undue admission of air, and these extremes can with practice be avoided. When the operation is not upon the mouth, nose or buccal cavity, by giving air alternately with nitrous oxide a prolonged anæsthesia can readily be obtained. As soon as the patient shows the signs of complete narcosis the face-piece is lifted and air admitted for three or four breaths, when it is replaced and more nitrous

oxide given. If cyanosis and jactitation are avoided an extremely satisfactory anæsthesia can be indefinitely obtained, only limited indeed by the supply of nitrous oxide. There is apt to be some rigidity in the muscles after a few minutes' inhalation, and the after effects are not always satisfactory, headache and even sickness not uncommonly occurring.

NITROUS OXIDE AND OXYGEN IN MAJOR SURGERY.

Of recent years a great advance has been made in the direction of extending the use of nitrous oxide to the needs of surgery, and to this end elaboration of apparatus has been effected.

Dr. Crile's researches into the etiology of shock have led him to believe that the anæsthetic which is employed during a prolonged operation, itself involving shock, may and does provoke the structural changes in the tissues of the nervous system indicative of shock. Comparing the results of shock when nitrous oxide associated with oxygen is used with those consecutive to ether, he believes that the former anæsthetic is less harmful. Further, he finds that the patient's condition is still more ameliorated by a preliminary injection of the alkaloids atropine, morphine, and scopolamine. Although the system suggested is, strictly speaking, a "mixed method," it is convenient to deal with it in this place.

Dr. Teter who has identified himself with this form of anæsthesia, has enjoyed a wider experience than any one else, having recorded many thousands of cases if we include minor with major operations. Dr. Gwathmey* has shown conclusively that when the gases or vapours of anæsthetics are adequately warmed at the time they enter the lungs, their narcotic effects are enhanced, while their liability to produce deleterious after effects is lessened. Dr. Teter's latest apparatus is simple and easily worked when once it is understood. It permits of adequate warming of the gases.

The apparatus.—This consists of a stand supporting four cylinders, two of nitrous oxide and two of oxygen, so that when one cylinder is exhausted a second may be turned on while the empty one is removed and replaced by a full one. In order that the best results may be obtained it is essential

* *New York State Jour. of Med.*, Feb. 1908.



FIG. 23.—The Teter nitrous oxide and oxygen apparatus for major surgery, with ether attachment.

that the gases be reduced from a high to a low pressure. This is accomplished by pressure regulators, which are incorporated in the head of the apparatus. It is possible by this means to obtain definite proportion of nitrous oxide and oxygen, which will continue to flow in the same proportion until a change is made by the anæsthetist. To obviate the possibility of the nitrous oxide "frosting," steam is forced through the nitrous oxide pressure regulator by means of a mechanism which is part of the vapour warmer.

After the regulators are adjusted to the desired pressure the anæsthetic is controlled by the controlling valves which are directly over the regulators. The dials are marked to show the number of gallons per hour that are being used. The cylinders are attached to these regulators and the regulators connected to the mixing chamber which is fixed to the supporting stand. Directly in front of the mixing chamber is attached the vapour warmer through which all gases must pass. The water in the warmer is kept hot by an electric heater or a spirit lamp. If a spirit lamp is used the flame is screened in so there will be no danger of igniting the ether vapour. Vapours passing through the warmer will be delivered to the patient at from 85° to 90° F., which Dr. Teter considers is the best temperature for inhalation.

There are times when it is necessary to administer a certain amount of ether with the nitrous oxide and oxygen when, for example, complete relaxation cannot be obtained by using the nitrous oxide and oxygen alone. An ether apparatus that can be used in connexion with the nitrous oxide and oxygen is necessary. Dr. Teter's ether attachment is connected directly to the vapour warmer. This consists of an arrangement of special mechanical parts to which a glass jar, which holds 10 oz. of ether, is attached. Any amount of ether from 1 to 20 per cent. may be taken up by the nitrous oxide and oxygen. The percentage of ether taken up is controlled by a single handle and the amount is designated on a dial which is on the top of the ether attachment. On the top of this attachment there is also an arrangement for controlling the direction of the outflow of the gases, as there are two outlets for the gases. The tubes throughout the

apparatus are wide bored to obviate respiratory strain. The face-piece, Dr. Teter likes to be made of celluloid, as this allows full view of the patient's face, and enables the anæsthetist to see if vomiting or displacement of the dental gag has taken place.

To and fro breathing takes place from the nitrous oxide bag, but cannot contaminate the oxygen in the oxygen bag. The rebreathing is controlled by using slight positive pressure and the amount of gases allowed to flow from the cylinders. A definite amount is allowed continuously as a definite amount of gases are continually flowing. By Dr. Teter's method of rebreathing he uses about 100 gallons of nitrous oxide and 20 gallons of oxygen per hour.

Those who employ this method, convinced by the arguments of Professor Yandell Henderson on *acapnia*, recommend systematic rebreathing. To Dr. Gatch* is due the credit for a careful and accurate presentation of the reasons for its adoption within safe limits. For nasal and post-nasal operations a nose cap is used in place of the celluloid face-piece.

Technique of method.—(a) Operations on regions other than the mouth and nose.

The patient is given a hypodermic injection of atropine gr. $\frac{1}{150}$ to gr. $\frac{1}{100}$, morphine gr. $\frac{1}{8}$ to gr. $\frac{1}{6}$, the amount given varying with the views of the administrators. Some authorities, notably Dr. Crile, add scopolamine gr. $\frac{1}{200}$ to gr. $\frac{1}{100}$.† Others again substitute an appropriate dose of omnopon for the morphine. The injection should be made one hour and a half or even two hours before the inhalation, and the patient should be kept very quiet in a darkened room.

The apparatus having been tested to see if all the arrangements are working, the mask is placed on the patient's face, and if the valves are working properly the nitrous oxide is turned on and a gentle stream of oxygen, at first about 2 per cent., is added. It is of the utmost importance that an even flow of gases should be maintained, and to effect this some positive pressure is necessary. If the supply is from

* *Jour. Amer. Med. Assoc.*, March 5, 1910, p. 775.

† The question of the employment of alkaloidal bodies and their dosage is considered more fully in Chapter VII.

large fixed tanks, being conveyed to the theatre by tubes, it is easy to compass the required pressure by means of a gas regulator, but if a portable apparatus is being employed, the end aimed at is obtained by having a spiral spring on a sliding collar which rests on the respiratory valve in the face inhaler. The amount of rebreathing is also controlled by this valve. If too much is permitted, the narcosis becomes too slight. The pressure required varies in the cases, and lies between 4 m.ms. Hg. and 40 m.ms. Hg. If cyanosis appears, more oxygen is allowed and this gas may at times be given by itself if asphyxial symptoms are present. Some slight degree of cyanosis is not regarded as dangerous, or indeed as being undesirable. To ensure accurate information about the state of the heart during a prolonged administration, a phonendoscope is fixed over the cardiac area and in the anæsthetist's ear. Recovery in normal cases takes place in a few minutes, but when the circulation and respiration are poor it takes longer. The induction period occupies two or three minutes. Dr. Teter adopts the usual criteria of the onset of anæsthesia and is guided by the colour, the character of the respiration and condition of the circulation in pushing or withholding oxygen or nitrous oxide. Unconquerable rigidity he has met with only in 10 per cent. of his cases, and as ether is always at hand this condition should be under control. He finds few serious after effects, but at times vomiting or headache may be caused. Age appears to impose no barrier, as very young infants and elderly persons have been anæsthetised for major operations by this method.

(b) All operations on the **upper air passages**, intra-nasal, intra-oral, or post-nasal, have been successfully carried out during the use of this method by Dr. Teter. In the cases of mouth and nose operations the anæsthesia is maintained by the nasal cap through which the gases are inhaled.

Dr. Teter has found that mixing nitrous oxide with air instead of oxygen does not lead to good results. Some points in the technique require further notice. The essential condition of an even flow of gases is obtainable by the pressure regulator, and no advantage is subserved by frequent changes in the quantities of gases, nor is any one proportion or percentage uniformly satisfactory in a number of cases.

Dr. Teter remarks * : " Numerous factors are responsible for this [lack of uniform results from uniform percentages], such as type of patient, depth and frequency of respirations, obstructed air passages, reflex from surgical trauma, position of patient and degree of shock encountered." He gives as averages 16 $\frac{3}{4}$ % of oxygen, 100 gallons of nitrous oxide, and 20 gallons of oxygen for an hour's anæsthesia. A close study of the patient's condition is really the only guide as to the proportions of gases to be used, although it is highly important to have these gases under known pressure, an end attained by pressure valves between the gas bags and the supply. There is grave danger if the pressure of the gases is allowed to be too great.

As to the risks associated with the method nothing at all precise can be said. Undoubtedly, although these gases when given for one inhalation by expert administrators may be considered as practically free from risk for all patients who are not seriously prejudiced by disease or exhaustion, the same immunity cannot be claimed for prolonged administrations. When alkaloids are also employed and when the patients are subjected to severe trauma and shock, factors other than the anæsthetic enter into the problem. Even the peculiar type of narcosis, light and evanescent, prone also to lack of uniformity and associated with some cyanosis with its physical counterpart respiratory and heart strain, may be harmful, either through embarrassing an operator accustomed to profound deathlike narcosis, and an elaborate technique involving the expenditure of much time ; or through the disabilities of a patient's respiratory and circulating mechanisms. As against these considerations we must accept the unhesitating statements of Dr. Teter and others in the United States, and of Mr. Page in this country. They have met with no deaths due to the anæsthetic, but the former has had the experience of some serious dangers. That such dangers do and must arise during severe operations whatever may be the method of anæsthesia adopted, is so well known that too much importance must not be attached to this statement.

* " The limitations of Nitrous Oxide with Oxygen as a general anæsthetic," *Jour. Amer. Med. Assoc.*, Nov. 23, 1912. To this and preceding articles by Dr. Teter the author is indebted for many of the facts dealt with in the present section.

There have been several deaths recorded in the United States which the reporters believe arose directly from the method employed, and all those who have had the widest experience admit that the plan needs expert knowledge and skill, and without these it is fraught with considerable danger. In Dr. Teter's personal practice he has had 11,559 cases of major surgery, 5,537 being of brief duration, 15 minutes or less, 336, 1 to 2 hours, 34, 2 to 3 hours, and 2, 3 to 4 hours; 2,496 oral operations, and to these 16,408 cases of extraction of teeth. One fatality* met with is regarded as having been due to shock and primary cardiac failure. Of the 16 other deaths noted by him, and which occurred outside his practice, no detailed description is available; details are not given beyond the statement that only 2 were directly due to the anæsthetic, although it was a contributory cause in others. Some ether also was employed for some of these patients.

The method appears inapplicable for children under five years of age, old persons with degeneration of their tissues, for alcoholics and men of great muscular physique.

When ether is used as a subsidiary agent some 2% to 8% is usually sufficient.

Mr. A. L. Flemming† has suggested a much simpler inhaler which enables the administrator to make the patient rebreathe the anæsthetics. The gases enter the inhaler by separate channels and are controlled by one valve.

Mr. H. M. Page‡ has gained some experience with this method and his success is certainly encouraging, and should extend its employment in this country.

Although in the main he adopts Teter's inhaler and method, he suggests that a better result is obtained when the gases are led into a bag near the face-piece, as is the case in Dr. Boothby's inhaler, and that the ether supply be immediately over the face-piece. Among a series of 94 cases of major surgery lasting up to an hour and fifty-five minutes in which only nitrous oxide and oxygen were used, are 51 intra-peritoneal operations. He recommends having

* 13,000 cases of $N_2O + O_2$ administration, *Jour. Amer. Med. Assoc.*, Aug. 7, 1909, p. 448.

† *Proc. Roy. Soc. of Med.*, section "Anæsthetics," March, 1913, p. 43.

‡ See *West London Medical Journal*, Oct. 1912, and *Proc. Roy. Soc. Med.*, section "Anæsthetics," March, 1913, p. 27.

300 gallons of nitrous oxide and 90 gallons of oxygen ready for a long case, and advocates rebreathing, both on account of Yandell Henderson's views on acapnia and on the score of economy. His technique includes a preliminary injection of alkaloids, and he considers omnopon gives better results than morphine. Advanced degeneration of the arteries, marked emphysema and all obstructive conditions of the air passages are, as Mr. Page rightly remarks, contra-indications as regards this method, and perhaps it is not too much to say that until a complete mastery of its technique has been obtained, and it is not easy even for experts, there should be even narrower limits imposed upon its adoption. The cases cited below (p. 126) indicate the danger of acute dilatation of the heart in subjects whose condition might favour such an occurrence, when nitrous oxide and oxygen or air is used for prolonged cases. Post-operative discomforts are markedly lessened by this method, so that diabetes and other cases of toxæmia appear to do better with it than with chloroform or ether or even with spinal anæsthesia. Mr. Page, indeed, is inclined to think that in states of serious collapse the patients are in better case than when spinal methods are adopted, since the drugs used in the latter procedures act, he thinks, more prejudicially than do nitrous oxide and oxygen. It must, however, be admitted that at present we are not sufficiently informed to speak without some degree of reserve about a method which may prove one of the best at our disposal, but which requires the utmost skill and unceasing attention on the part of the anæsthetist at once to safeguard the patient, and to ensure an even and tranquil anæsthesia. A further word of caution is necessary since this method as practised by Dr. Teter and his school is essentially a *mixed method*, and as such all the conditioning factors must be studied. In practically every case alkaloids are injected before the gases are administered, viz., morphine (or omnopon), scopolamine, and atropine. These, although most valuable, yet exert some distinct effect upon the respiratory centre, and in cases in which the morphine effect predominates there is danger of respiratory failure through the depression of respiration and the cyanosis incident to prolonged flooding of the lungs and pulmonary

circulation with the gases nitrous oxide and oxygen. However, Dr. Teter assures me that no such dangers have occurred in his practice.

DEATHS DURING NITROUS OXIDE ADMINISTRATION.

In the return of deaths under anæsthetics published by the *Lancet** thirteen under nitrous oxide are given. The causes assigned are (1) asphyxia; (2) fright (imperfect anæsthesia); (3) congestion of the lungs, which was not known to be present when the anæsthetic was administered; (4) phthisis (last stage); (5) asphyxia due to impaction in the larynx (*a*) of a broken gag, (*b*) of a molar tooth; (6) syncope (three cases), shock of extraction of a tooth in semi-anæsthesia, while in one case the cause of death assigned was tight-lacing interfering with respiration and circulation. Three other cases are given in this Report in which respiration failed, but the patient's life was saved by prompt recourse being had to artificial respiration. In a paper written by the author† sixteen deaths are tabulated and classified, but some of these are identical with those mentioned above, three additional being supplied.

The following recorded cases are given as records of accidents which have actually occurred, and are arranged to facilitate the student's study of this subject. It is hoped that such concrete examples will assist the student more than any mere tabulation of dangers and difficulties can possibly do.

CASE I.—In Dr. Maughan's‡ case the patient was a young woman suffering from an abscessed left tonsil with peritonsillar inflammatory œdema, but no marked dyspnœa, although dysphagia is mentioned. Nitrous oxide was given to her while she sat in a chair, but it was, it is stated, not pushed to its extreme degree. Respiration stopped as soon as the mask was withdrawn and complete obstruction of the air passage developed rapidly, due to engorgement of the tongue and

* "Report of the *Lancet* Commission appointed to investigate the subject of the administration of chloroform and other anæsthetics, from the clinical standpoint," 1893, p. 175.

† *Brit. Dent. Jour.*, Oct. 1895, p. 65.

‡ *Transactions of Society of Anæsthetists*, vol. vi., p. 12.

faucial tissues. The patient was placed horizontal and laryngo-tracheotomy was performed, and the colour changed from black to normal, and the pupils contracted. Spontaneous respirations were started by Howard's method, but the patient ultimately died within nineteen minutes. Inversion is not mentioned. This case appears to be similar to those noticed below (p. 126), and to have been due to septic weakening (? dilatation) of the heart, associated with primary asphyxia, itself the result of the combination of impaired pulmonary circulation through the inhalation of nitrous oxide and the state of the heart.

CASE II.—In another case the patient suffered from angina Ludovici, and a house surgeon at a London hospital gave him nitrous oxide with the view of incising the brawny tissues of the neck to relieve tension and liberate pus. The nitrous oxide produced asphyxia through venous engorgement, and as the air passages could not be rapidly opened, death resulted. The septic factor in this case should be noted.

CASE III.—This case is recorded by Mr. A. Granville.* The patient, a youth of seventeen, apparently healthy, was given nitrous oxide and oxygen, and at times became slightly dusky. After twenty minutes, the youth having apparently resumed consciousness sufficiently to move and groan, chloroform was given by an open method. After four or five minutes, the heart's action became imperceptible, but respiration went on for five minutes when he died. It was suggested, with what seems great probability, that the heart muscle dilated acutely under the strain imposed by the prolonged nitrous oxide and oxygen administration, and was therefore rendered vulnerable to the action of the chloroform, which, as Prof. McWilliam has proved, acts not only as a cardiac depressant but causes acute dilatation of the heart itself.

CASE IV.—Mr. G. Norman Bennett† has recorded the following death under nitrous oxide. The patient, a boy aged 17, had diseased glands in the neck, especially in the lower part. There was no appearance of dyspnoea, and he had within a few days taken gas without untoward effects. The anæsthetic was given by a junior hospital officer. Before

* *Transactions of Society of Anæsthetists*, vol. ii., p. 175.

† *Op. cit.*, vol. vii., p. 1.

stertor was heard the mask was removed and the dental operation commenced. Shortly afterwards cyanosis appeared, the operation was stopped and tongue traction practised, but respiration ceased, then artificial respiration was adopted, and several spontaneous breaths were taken. A futile attempt at a low tracheotomy was made, but the patient died. It was subsequently discovered that a few weeks previously gas had been given him in the out-patient department, and on this occasion he nearly died, and was admitted to the hospital as stridor persisted, when it was found that he suffered from lymphadenoma. The necropsy showed that his trachea was surrounded by glands and compressed to half its normal diameter. The heart muscle was degenerated.

CASE V.*—This was also a dental one. The patient was a man aged 33, who suffered from glandular enlargement of his neck, but without dyspnœa. There was nothing abnormal revealed by laryngoscopic examination. An experienced anæsthetist gave the anæsthetic, and the period of induction revealed nothing unusual. There was no stertor, and the mask was removed after one and a half bagfuls of gas had been inhaled, as some cyanosis appeared. Air was freely admitted throughout. The anæsthesia was complete, but with the extraction of a tooth respiration ceased, and resuscitative measures, although they restored the normal colour, did not save the life. The necropsy showed that the masses of glands had pushed the trachea to the right and somewhat narrowed the air-way. The left pleura was adherent and the right lobe of the thyroid was enlarged and contained areas of suppuration. The glands and thyroid proved to be carcinomatous.

CASE VI.—A fatality recently occurred in the practice of a skilled anæsthetist when nitrous oxide and oxygen were given to an elderly man for a dental operation. The patient had been seen by a medical man and, although known to have circulatory trouble, was pronounced to be fit for the anæsthetic. Death without any premonitory signs of danger occurred as the dental operation was completed. The patient suffered from angina pectoris, and the death was no doubt primarily due to this disease.

* Narrated by Dr. McCardie, *Transactions Society of Anæsthetists*, vol. vii., p. 21.

DANGERS—ULTIMATE RECOVERY.

The following cases exemplify some of the dangers which, if not peculiar to this anæsthetic, are liable to produce alarm and serious risk to life. It must be remembered that although in some instances the results were only indirectly related to the anæsthetic, yet it was an important factor in their development.

CASE A.—A strongly built but healthy man of about 60 had gas and oxygen given him by a skilled anæsthetist, and a tooth was extracted. No unusual symptom occurred during the induction or operation. The return to consciousness was delayed by some minutes; the patient seemed dazed, and it was found that he could not hold the glass of water and that his speech was thick and indistinct. It was evident that the patient was hemiplegic. The condition was very slight and passed off in a very short time.

CASE B.—A man of about 50 who had for years suffered from cough due to dilatation of bronchi, chronic bronchitis, and some emphysema, was given gas and oxygen without any unusual symptoms. A premolar was extracted, but lost sight of, and on the patient's resuming consciousness he had a fit of coughing. Careful search had been made for the tooth, but without avail. There was no distress in breathing, and not more than the usual bouts of coughing. Careful and repeated auscultation and laryngoscopy afforded no evidence of a foreign body in the air passages, nor were there any symptoms. Many months later, however, after a severe fit of coughing, the tooth was expelled with a good deal of mucopurulent fluid. It is unusual for a foreign body to enter the air passages without causing urgent dyspnœa, at all events for a time after its entrance.

CASE C.—A similar occurrence took place recently at the Royal Dental Hospital when a student was operating. Luckily, on measures being promptly adopted, although the root of the tooth could not be felt, it was coughed up before the patient left the hospital. There were no marked signs of respiratory distress.

In the Report of the British Medical Association, July, 1900, out of 2,911 N_2O cases 21 are given as complicated;

vomit causing asphyxial symptoms, micturition, and in one defecation are recorded. The first condition seems to be preventible by abstention from food, while the last two probably reveal a faulty method, as they commonly arise from anoxæmia causing muscular spasms. As regards vomiting, some persons retch and vomit even when they have been quite carefully prepared for the anæsthetic.

CASE D.—Mr. R. W. Collum * has recorded a case in which repeated attempts on different occasions to obtain anæsthesia with nitrous oxide failed. The causes of this are nervousness, the use of too large a gag, since many persons retch directly their jaws are held apart, and an unduly sensitive pharyngeal mucous membrane. The remedies are to use a gargle, spray the throat with a weak solution of cocaine, and insert only a very small prop in the front of the mouth, replacing it by a gag as soon as the induction is complete.

CASE E.†—The patient was a delicate girl, the operation avulsion of a toe-nail. The heart and lungs were normal before inhalation. Induction by gas and air normal, the operation was commenced and the mask withdrawn to admit air. On re-application, some cyanosis developed, respirations 40 to 50, and engorgement of the neck veins. Half air and half nitrous oxide was given, but the blueness increased and the breathing became slow and shallow, while the pulse grew weak and "running" and very rapid. The pupils were dilated, but reacted to light; the conjunctival reflex was absent. The apex beat was displaced one inch outside the nipple line, and the heart impulse was felt over a wide area, and over this could be heard a loud blowing systolic murmur conducted outwards to the mid-axillary line. These signs all disappeared within fifteen minutes of the commencement of the induction, the only sequela being headache. Some days subsequently this girl was given chloroform without anything abnormal occurring.

CASE F.‡—The patient, a nurse, suffering from a septic arm, was given gas and air for two minutes. In this case also

* *Proc. Roy. Soc. Med.*, 1912, section "Anæsthetics," p. 14.

† Reported by Mr. Francis, *Trans. Soc. Anæsthetists*, vol. iv., p. 7.

‡ *Ibid.*, vol. ii., p. 185, and vol. iii., p. 9. Cases mentioned by Mr. H. C. Crouch.

the apex beat was displaced outwards (for two inches) and a systolic murmur was heard while evidence of acute dilatation was present.

CASE G.*—Patient, a girl suffering from a septic leg. Gas and oxygen were given, no cyanosis supervened, but the heart, which was auscultated throughout the inhalation, was found to have rapidly dilated, although no murmur was heard.

CASE H.†—A lad of 16 with a goitre was sent to the Charing Cross Hospital for advice. On reaching the hospital he turned his head to speak to some one, and the pressure of the goitre produced occlusion of the trachea. He was brought in in the last stage of asphyxia and only the prompt opening of his windpipe saved his life.

CASE J.‡—A healthy looking young woman came to the Royal Dental Hospital, and the presence of a goitre was overlooked. When the anæsthetist gave her gas and air she was enveloped in a mackintosh apron which prevented his noticing the tumour. The induction was normal and the anæsthetic was pushed to allow several teeth to be extracted. In attempting to extract a lower tooth, presumably the tongue was forced back and the lower jaw depressed. The breathing stopped at once, the colour was ashen, the pupils widely dilated, the globes turned up and the conjunctival reflex absent. The gravity of the case was recognised, the patient lifted on to the floor and the head *placed in the line of the body*. Respiration was easily restored. In both cases the pressure of the goitre was apparently determined by the position of the head, and the occlusion of the trachea caused extreme engorgement of the veins.

CASE K.§—Patient, a man aged 24, suffered from multiple osteo-arthritis, involving both mandibular joints so that the teeth could only be separated for $\frac{1}{2}$ inch.

Operation, removal of teeth and stumps.

* Reported by Mr. Francis, *Trans. Soc. Anæsthetists*, vol. ii., p. 185, and vol. iii., p. 9. Second case mentioned by Mr. H. C. Crouch.

† *Trans. Soc. Anæsth.*, vol. vii. pp. 37-39. Mr. Carter Braine describes this and the following case in detail, and points out that the experience gained in the one guided his treatment in the second.

‡ *Ibid.*

§ Reported by Mr. H. Relph and Dr. Rood, *Brit. Med. Jour.*, 1910, vol. i., p. 1287.

Nasal respiration was quite free, so nitrous oxide was given by that route. Slight cyanosis developed after a normal induction, and one stump was extracted. Cyanosis increased, and respiration stopped. The patient was placed on the floor, the mouth opened by force, the tongue pulled forward and the pharynx cleared of viscid mucus. Artificial respiration failed to effect air entrance into the lungs, so tracheotomy was performed, when air entered freely and the patient rapidly recovered. The obstruction in the larynx appeared to be due to venous congestion. Chloroform was given through the tracheotomy tube on the next day and all the stumps successfully removed. Such cases seem therefore to negative the use of nitrous oxide, and to indicate the employment of chloroform.

In connexion with these cases that mentioned (on p. 123) and reported by Mr. Granville may be studied, as well as Sir F. Hewitt's case (see p. 100). It would appear that the main dangers to life under gas are those which arise (1) through interference with respiration, and (2) those in which the blood-vessels or heart suffer probably, however, secondarily to respiratory strain.

The cases of foreign bodies entering the air passages—accidents incidental to the operation—are considered later, so that in this place attention is invited to effects due directly to the anæsthetic, although no doubt the state of the patient at the time of the administration constitutes a contributive or determining factor.

The theory cannot be sustained that septicity is alone responsible for the acute dilatation of the heart resulting from the respiratory strain produced by the entrance of a foreign gas into the blood-stream and the lessening of the oxygen supply through the loss of carrying power of the erythrocytes, since in some instances no septic condition was present. However, we know that both anæmic and septic conditions cause degenerative changes in the myocardium, and this probably renders the heart predisposed to acute dilatation, even when no obvious asphyxial complication exists. It seems likely that when slight faintness or even syncope follows the use of this anæsthetic an acute dilatation is present although it is not appreciated. In prolonged inhalation such as by the nasal method or by such a plan as that of

Dr. Teter, such a development should be most liable to occur, so that its rarity indicates that it is by no means a constant danger, but is rather a possible accident to be kept in mind in the case of certain types of persons. The deaths arising through pressure upon the trachea by masses of glands or by a goitre demonstrate two points: (1) the absolute necessity for preliminary examination of the patient's fauces and neck *in all cases*, and (2) the substitution of some other anæsthetic, probably chloroform, in severe forms of such diseases. The mere absence of dyspnœa during consciousness is no criterion of safety as it is often absent, since severe dyspnœa may develop as soon as the muscles fail to maintain the trachea in the position of safety. In such patients any cyanosis, and its avoidance cannot be ensured in their case, at once produces venous engorgement, and a vicious circle is engendered which leads to death.

The references are given that a full study can be made of the cases. A general summary of the actual causes of the deaths may be useful as supplementing the observations which have already been made. In most cases the death could not have occurred simply as a result of nitrous oxide inhalation. In at least three cases the patients suffered from conditions which rendered the upper air-ways constricted, and liable to complete closure if any marked venous engorgement arose, such as might occur during the inhalation of nitrous oxide. Œdema, inflammatory swelling affecting the tonsils, tongue, larynx and adjacent tissues, are extremely likely to cause asphyxia when nitrous oxide is inhaled; the patients suffering from such conditions are not satisfactory subjects for this anæsthetic. A goitre and enlarged glands may produce dangerous symptoms. Spasm of the larynx has been reported and its possible supervention, even without the mechanical irritation caused by fragments of teeth, etc., must be remembered, as death has resulted without impaction of foreign bodies in the larynx when the patient was under nitrous oxide. This spasmodic closure probably was the cause of one of the deaths and followed inhaling impure and irritating gas. Cough and difficulty of respiration should always suggest this possible complication and the gas should be tested before the patient is allowed to inhale it, if the first

attempt causes severe laryngeal irritation. The administrator can easily determine whether the gas is impure by himself inhaling a few breaths of it. As to syncope, undoubtedly deaths have arisen from heart failure; these result either from fright and incomplete anæsthesia alone, or more usually these states are contributory to inducing cardiac failure in the anæmic and feeble, due, it seems probable when the cases given above are considered, to acute dilatation of the heart.

Suffocation, either from foreign bodies, *e.g.* vomit, sponges, etc., blocking the air passages, has in some of the cases caused death, a death which arose from mechanical causes and not from the action of the anæsthetic.

It is difficult to be sure whether nitrous oxide has ever been directly the cause of death. If it is used in an impure form, or if given to persons suffering from some asphyxial symptoms in whom respiration is already seriously interfered with, nitrous oxide is undoubtedly a dangerous anæsthetic, and potent to lead to serious results. The heart seems seldom primarily affected, but in the feeble and asthenic it is certainly liable to fail should the respiration be in any way hampered, so that syncope can thus be brought about and may prove fatal. An undeniable danger exists in the case of persons who are alcoholic or have taken alcohol immediately before inhaling an anæsthetic. They become greatly excited, and struggle, so that owing to the tonic rigidity of the muscles concerned in respiration a severe strain is imposed upon respiration and the heart which may determine a rupture of a blood-vessel or overfilling of the right ventricle, with consequent syncope.

SUMMARY OF THE USES AND MANAGEMENT OF NITROUS OXIDE IN MINOR AND MAJOR SURGERY.

Preparation.—No special preparation is required; food is best avoided for some time before inhalation, and delicate, stout, and elderly persons should be cautioned not to fatigue themselves, or to hastily climb upstairs before taking it.

Clothing should be sufficiently loose to permit full breathing

and the *neck coverings* must be removed. Abdominal and hernia belts are best left on, indeed I have known a hernia to descend during the straining such as may occur in nervous people.

Posture is always most important, and, as was pointed out above, should be comfortable and easy, with the head in the body's axis, and none of the muscles in tension. If a protecting mackintosh is laid over the neck and chest its arrangement should not obscure a complete view of the patient's respiration. Struggling is usually due to unnecessary forcing of the anæsthetic; this should be avoided, but when the patient's breathing assumes its normal force and rhythm the anæsthetic may be pressed. If oxygen or air is given with the nitrous oxide, and one or the other should always be employed, the indication for admission of either is the appearance of cyanosis or rapid supervention of subsultus and stertor. This plan lengthens the period of induction, so permitting a larger amount of the anæsthetic to enter the circulation. When the mask is removed and the operation is commenced, the anæsthetist must watch the patient's colour and respiration and at the same time take any steps necessary to avoid accidents associated with the operation. He fixes the head with his right hand, and as soon as his left has hung the inhaler within reach, it can be used to hold a mouth-spoon behind the region of extraction to catch stumps or teeth. A gag must be at hand, as its insertion will be necessary if the dental prop slips or in the event of the operator operating consecutively on each side of the mouth. Cyanosis is usually due to pushing back of the tongue by the operator's fingers, and, provided some respiration takes place, this may be ignored in healthy subjects for one or two respirations, but if the patient is feeble or the heart of doubtful vigour, air must be admitted by the fingers being lifted. Pushing forward the mandible from behind the angle will usually lift the tongue and start a respiration. If while extracting lower teeth the chin is forced down on to the chest some obstruction to respiration will occur; when this is so, the correct position of the head and of the jaw must be restored. The blood either from the nose, or from the gums in multiple extractions, is apt to flow back to the epiglottis unless care is taken to keep the

head straight or even a little forward. A sterilised swab of gauze or a marine sponge should be at hand to remove the blood, which otherwise may interfere with breathing, or if it is swallowed may occasion nausea and vomiting. If a sponge is placed over the gums after extraction it must be secured by a long looped string outside the mouth. If the dental prop has slipped and the teeth become clenched great care must be taken to introduce the closed gag somewhere in the region of the molars or premolars, by preference at the spot where there is a gap. If put between the incisors and pressure is used these teeth may be forced out. In cases of severe trismus a very small wedge secured outside the mouth will usually enable an anæsthetist to slip in a gag and separate the jaws when unconsciousness has supervened.

The period of recovery is seldom marked by any noticeable incidents. Pallor or feeling "weak" and "sleepy" is often complained of, and then the patient should be persuaded to inspire deeply, or, if necessary, the head can be lowered. A patient should never be hurried out of the chair or be allowed to stand for some minutes after the inhalation. Weakly persons or those who "feel bad" had better be kept in a room on a sofa for half an hour.

If remedial measures such as artificial respiration, laryngotomy, and so on have to be undertaken, the patient should be placed on the floor, as these procedures cannot be carried out effectually in a dental chair. The anæsthetist should assure himself before the patient's recovery that the jaw has not been subluxated or dislocated. Props should not be removed until the patient is conscious, except in emergencies.

CHAPTER IV.

ETHER.

THE METHODS OF USING IT.

INTRA-VEINUS INFUSION OF HEDONAL.

Ether or ethyl oxide was discovered in 1540 by Valerius Cordus and named by him *oleum vitrioli dulce*. In 1730 Frobenius substituted its present designation. Ethyl ether must be carefully distinguished from "compound anæsthetic ether," a mixture of amyl and ethyl ether which is used solely for producing local anæsthesia.* "Compound anæsthetic ether" cannot be safely used for producing general anæsthesia—indeed, the attempt has resulted in fatal accidents.

Chemical and physical properties.—Ether, known also as sulphuric ether, is ethyl oxide $(C_2H_5)_2O$. It is prepared by the action of sulphuric acid on ethyl alcohol. When pure it is a colourless, transparent, mobile liquid with a penetrating odour. Boiling point, $35^{\circ} C$. Sp. gr. 0.720.

Numerous qualities and varieties of ether are sold. These fall into two groups:—

- (a) Those prepared from duty-paid rectified spirit ;
- (b) Those prepared from industrial alcohol, which is exempt from duty, and contains 5 per cent. of wood naphtha.

The presence of methyl alcohol in the wood naphtha used in the industrial alcohol causes the ether derived therefrom to contain methyl oxide $(CH_3)_2O$, and methyl-ethyl oxide $CH_3O.C_2H_5$. These bodies have a lower boiling point and

* See Chapter XI.

specific gravity than ethyl oxide, hence the so-called "methyiated" ethers commence to boil below 35° C. and have a lower specific gravity than the corresponding product prepared from pure alcohol. The variations in the sp. gr. of commercial ethers is also caused by the presence of varying proportions of alcohol and water.

The following are the chief qualities sold by manufacturers:—

Ether Pure 0.720.

Pure ether from rectified spirit. Nearly free from water.

Ether Pure 0.735.

Ether from rectified spirit, but containing nearly 10 per cent. of water and alcohol.

Ether Meth. 0.717.

Prepared from industrial spirit. Nearly anhydrous, but contains methyl oxide. It commences to boil at about 20° C.

Ether Meth. 0.720.

Prepared from industrial spirit. It contains small varying proportions of alcohol and water. It usually contains traces of aldehyde and peroxides.

Ether Meth. Purif. 0.720.

Prepared from industrial spirit, but is free from impurities, and should comply with the tests given below, except perhaps that for peroxides.

Ether Meth. 0.730 and Ether Meth. 0.735.

Prepared from industrial spirit. They contain water and alcohol and are intended to be used as solvents and for technical purposes.

The following are the principal tests for ether intended to be used as a general anæsthetic.

Residue.—20 c.c. allowed to evaporate from a glass dish should leave no residue. The dish should be warmed on a water bath to dispel the film of moisture which is attracted from the air by the ether during evaporation.

"Smell" Test.—When 10 c.c. or 20 c.c. are poured over a filter paper and allowed to evaporate, it should not be possible to detect any foreign odour at any stage of the evaporation, and the paper should be quite odourless after complete evaporation of the ether.

Free Acid.—When the sample is shaken with an equal volume of distilled water and a piece of blue litmus paper is dropped into the mixture, the colour of the litmus should not be changed or discharged.

Water.—Anhydrous ether forms a clear mixture with an equal volume of carbon bisulphide. Ether Meth. Purif. 0.720 often contains traces of water and does not comply with this test.

Aldehyde.—When a stick of potassium hydroxide is immersed in the sample of ether, no discoloration of the liquid or of the potassium hydroxide should occur within two hours. Many of the ethers offered for anæsthetic purposes do not comply with this test.

Peroxides.—When the sample is shaken with half its bulk of a dilute solution of potassium bichromate acidulated with sulphuric acid and the mixture is set aside, the supernatant ether should be colourless. If peroxides are present, perchromic acid is formed, which dissolves in the ether and imparts to it a blue colour. In order to comply with this test and with the test for aldehyde, the ether must have been kept from the light, since a comparatively short exposure after purification in manufacture is sufficient to develop traces of peroxides and aldehydes.

General properties and uses.—Ether is an exhilarant and finally an anæsthetic.*

As a general anæsthetic ether possesses an advantage over nitrous oxide gas in so far as it produces a more prolonged and profound narcosis. It is believed to be safer than chloroform as it is not a protoplasm poison, and does not prejudicially affect the heart. It raises blood pressure. It is therefore to be recommended for general use. The allegation that ether produces more dangerous pulmonary after effects than chloroform has been urged, but cannot be said to be entirely proved, and very many of the reputed disadvantages of ether are undoubtedly due to faulty administration rather than to any inherent peril in its action upon the tissues. This point will be again considered when the after effects and sequelæ are considered. Probably the greatest danger which may arise through the incautious use of ether is the exhaustion

* For the use of ether to produce local anæsthesia, see Chapter XI.

following undue stimulation, but strangely enough this aspect of the matter has received but slight attention : it will be dealt with later on (p. 208).

It must, however, be borne in mind that ether has its limitations, a fact which is often overlooked, with the result that failure and disappointment follow in certain cases, both of which might have been avoided had a more careful selection of the anæsthetic been made.

Contra-indications.—Cases in which ether should not be used except by special methods, *e.g.* Crile's tubes, intra-tracheal insufflation, or intra-venous infusion :—

1. In protracted operations about the mouth, jaws, nose, or pharynx, which necessitate the mouth and nose being uncovered. Since consciousness rapidly returns when the supply of ether is discontinued, there is not time for the prolonged surgical procedure.

2. In all operations which require the employment of the actual cautery, or lighted candles, lamps, etc., near the mouth.

In the following conditions the advisability of using ether ought to be carefully weighed :—

Persons who are suffering from *bronchitis*, the *emphysematous* (if the condition be very pronounced), and as a rule *asthmatics*, bear ether badly, since it excites cough and may clog the bronchial tubes with a quantity of excessive secretion. On the other hand, ether often assists the breathing of asthmatics if pure and copiously diluted with air.

In *renal disease*, when extensive, ether is said to induce suppression of urine, so that if given at all in these cases it should be used with the utmost caution.

The vascular excitement to which ether gives rise contra-indicates its use for persons with *rigid* and *atheromatous arteries*, or in whom circulatory perturbation is likely to be harmful, especially if the method employed imposes some air exclusion, since the added asphyxial condition will still further raise the blood pressure. It is obvious that when *cerebral hæmorrhage* from rupture of an artery has once occurred, ether might, by increasing arterial tension, induce a repetition of so dangerous an accident. Some few instances of this have occurred.

In *infants* and *very young children* ether may sometimes produce pulmonary trouble from its irritating effects upon the delicate mucous membrane of the respiratory tract.

Although, in selecting an anæsthetic, it is well to weigh these considerations, yet I think few of them are insuperable objections to ether, except perhaps in very marked cases of disease.

In *tropical climates* it is difficult to obtain and to keep ether, and also to administer it satisfactorily.

As ether often provokes rapid breathing and not infrequently coughing before complete narcosis has been obtained, it should not be used when these are prejudicial to the patient, or to the success of the operation—for example, in some operations on the eyes. Many surgeons object to ether in abdominal operations both on account of the inconvenience arising from the rapid laboured breathing often caused by it, and because they consider the patients are especially liable to pulmonary troubles after the operation. As will be seen in the sequel, the associated employment of alkaloids with ether, and the adoption of an open method, enable the anæsthetist to surmount many of these difficulties, so that the majority of abdominal operations at the present time are performed under ether. It is not, however, wise to adopt ether as a routine anæsthetic for such cases, since in many instances the well-being of the patients after the operation is certainly prejudiced by employing ether. Chloroform, assuming it is given by scientific methods, is for such persons a safer anæsthetic.

In *operations upon the brain* or spinal cord, when turgescence and dilatation of the blood-vessels are undesirable, ether should not be used; and according to Prof. Wood it is contra-indicated in the presence of brain tumours.*

PHYSIOLOGICAL ACTION OF ETHER.

Hermann asserted that ether causes the destruction of the red blood corpuscles. Dr. Da Costa,† of Philadelphia, has

* Recently the open ether method associated with a preliminary injection of alkaloids has been used in the surgery of the nervous system. It is said to be free from objection, but I have no experience of it, and should hesitate to adopt it in preference to dosimetric methods of using chloroform when associated with oxygen.

† "The Blood Alterations in Ether Anæsthesia," *Medical News*, March, 1895.

found that it produces a marked diminution in the hæmoglobin, more especially in persons whose blood is pre-existently diseased (*e.g.* anæmia, chlorosis, etc.). Bernard shows that infusoria were readily influenced by ether, and Sternberg has demonstrated that it destroys pathogenic bacteria. Graham states that large quantities of ether destroy phagocytosis for days or even weeks.

Prof. F. Keeble* has discussed the effects of anæsthetics upon the lower organisms. His experiments support the conclusions of previous workers. Thus ether will parase protoplasm, whether vegetable or animal, but will only destroy it when used in great strength and for a prolonged time. Certain bacteria are positively chemiotactic towards ether (Rothert). Nathanson found that ether causes cells usually dividing by karyokinesis to become subject to amitotic division. According to Wilson the eggs of *Toxopneustes* while under the influence of ether lose their asters. The effects of ether upon flowering plants, although interesting, are hardly germane to our present subject, so readers interested in the subject should refer to Prof. Keeble's paper, which supplies an excellent bibliography on the matter.

When the pure vapour is first inhaled it induces a burning sensation in the mouth, pharynx, and throat, and a feeling of impending suffocation. It appears to act in two ways; indirectly through the nerve centres as a powerful deliriant and anæsthetic, and directly upon the endings of the nerves supplying the pharynx and respiratory tract. Thus, it increases the flow of saliva, and causes considerable discharge of watery secretion from the mucous membrane of the respiratory tract. Its extreme volatility makes it exert a marked cooling action upon the skin and mucous membranes when it is brought into contact with them; and the vapour may, if injudiciously employed, excite catarrh. Ether is absorbed both by the mucous membrane of the respiratory tract and that of other mucous surfaces, *e.g.* the rectum. When ether vapour is given by the rectum, the vapour is perceptible in the breath after a few minutes. When delivered directly into the trachea as by the intra-tracheal insufflation method the

* *Trans. Soc. Anæsth.*, vol. viii. p. 31.

action is very rapid, and unless the vapour is warmed before entering, it cools the lungs more than when it is inhaled in the ordinary way, and so lowers body temperature. Ether, when infused with saline into the blood-stream, produces narcosis very quickly. It can be recognised in the patient's breath within a minute of its entrance into the vein.

Intra-muscular injections of ether also produce narcosis, but the absorption is less rapid than when introduced by other channels.

The nervous system during etherisation becomes profoundly affected. The cerebrum first succumbs. Excitement and hallucinations occur, the patient believing that he is engaged in some active exercise; he often grows pugnacious or amatory, or pursues his habitual work or pastime; he may struggle and cry out. Soon his speech becomes thick and inarticulate, his struggles cease, and his mind no longer controls his movements. The *sensory nerves* of the spinal cord then fail to convey impressions from without, although stimulation of the motor nerves induces movements. Later, the motor nerves also cease to respond, save to powerful electrical excitation (Longet). Waller has shown that isolated nerve is directly influenced by ether, and that ether is about seven times less potent in this respect than chloroform. The *medulla oblongata* becomes next affected; at first sensory impressions fail to reach it, finally its centres become paralysed, respiration is arrested and the heart ceases to beat. It appears that these results are due to the direct action of ether conveyed by the blood to the nervous centres, since they occur after section of the pneumogastric nerves, or when the anæsthetic is injected directly into the veins. Hence it would seem that ether, directly affecting the centres, acts first as a stimulant, and later as a paralyant. When artificial respiration is maintained, the heart will continue to beat for a prolonged period, and this in spite of very large quantities of ether being taken, since ether is not in the ordinary sense of the term a protoplasm poison, or, perhaps it is more consonant with our present knowledge to say, is an extremely weak one. It kills either by rendering the vital centres unable to take up oxygen or by exhausting them through over-stimulation.

Ether narcosis may be divided into five degrees (Snow) as in the case of chloroform.

The phenomena of these may be summarised as follows:—

(1) All the effects that exist while consciousness is still present; a burning pungent taste and smell; buzzing or singing in the ears; inability to recognise objects in the proper places, as they appear distant and unduly large; the speech of bystanders often imperfectly understood and misapplied. (2) The mental faculties become impaired but are not suspended, illusion, semi-delirium, excitement, and muscular movements appear, but are of a subjective rather than of an objective significance. Semi-anæsthesia exists, and pain, even if slightly felt, is seldom remembered as pain upon awakening. This is probably the degree of which the French surgeon Péan wrote when he described patients who moved freely and appeared conscious, but were nevertheless oblivious of the surgeon's knife. This condition is similar to the unconsciousness to painful stimuli evinced by persons intoxicated by alcoholic beverages. Rigidity and muscular spasm usually appear as the patient passes into the next degree. Of especial significance is spasm of the larynx and of the respiratory muscles; however, laryngeal spasm under ether is more commonly the result of a sudden presentation of strong ether vapour to a larynx whose sensibility has not been lessened by gradual anæsthetisation. (3) All the mental faculties are in abeyance, the muscles relax, and no movement of the voluntary muscles takes place, nor is any pain felt. Occasionally patients will wrinkle up their brows or even moan throughout an operation, but these are not indications of sensation or pain. (4) Paresis of the centres of the *medulla oblongata* supervenes with gradual failure first of respiration and then of circulation; and (5) death results from destruction of these centres and consequent stopping of the heart. Patients may be restored during the fourth degree by the performance of artificial respiration, but probably not when the circulation has ceased in the fifth. Recovery can undoubtedly follow even when *apparent* arrest of the heart has taken place, since the circulation may be carried on although feebly when the heart appears not to be acting.

Duret* divided ether narcosis into two periods:—(1) anæsthetic sleep—cerebral excitation, followed by abolition of cerebral function and disappearance of sensibility; and (2) anæsthesia—muscular resolution and abolition of reflexes. Dastre points out that the order in which sensation is lost is one of primary importance. The following is the succession in which sensibility disappears:—that of the integument of limbs and trunk, next that of the face, then that of the nasal mucous membrane, followed by that of the eyes, then that of the organs of sense, the ear being the last to fail. It may be noted that the genital organs and rectal mucous membrane retain sensibility to stimuli for a very prolonged period. The knee jerk is increased in the early stage of etherisation (Eulenberg), and even in the second degree ankle and knee clonus are apt to develop, and as a rule more profound narcosis will cause the phenomena to cease. A curious and troublesome phenomenon of ether narcosis is ether tremor.† It comes on at the end of induction, the whole limb shakes, often with great violence, and the tremor is increased by any attempt to control it. I have seen it occur even when conjunctival reflex was completely lost and the respiration was slightly stertorous. It is even more common in the lighter narcosis characteristic of "open ether" than in the more profound narcosis reached when a closed method is pursued (see below, p. 210).

In the rhythm of *respiration*, ether brings about marked changes. If the full strength of ether vapour be allowed to impinge upon the glottis, the adductor muscles are thrown into spasm, and the rima glottidis becomes temporarily closed. Ether may thus cause laryngeal spasm (Kratschmer). Indeed ether has been shown by Horsley and Semon to exert a marked local action upon the laryngeal muscles. These observers have demonstrated that this differs according to the depth of the narcosis induced. Slight narcosis causes adduction, while deep etherisation produces abduction of the vocal cords, and these results obtain alike with strong or weak faradic currents, and whether the recurrent laryngeal nerve is divided or left intact.

* Quoted by Prof. Dastre, "Les Anæsthétiques," p. 77.

† This is allied to the condition known as kidney clonus, which is especially liable to be elicited when the patient is under ether.

During ether inhalation the respirations are at first hurried and deep, subsequently they become slower and more shallow, and eventually, if ether is pushed to a dangerous extent, cease altogether. Provided the respiratory acceleration is only moderate it assists circulation and so raises blood pressure; if excessive, it has the opposite effect, and by increased lung ventilation lowers the tension of carbon dioxide, producing an acapnic condition.* Failure of respiration is rapidly followed by cessation of the heart beat. Such effects are also produced by exhaustion following over-stimulation, and this should be kept constantly in mind when an inhalation is likely to be greatly prolonged. This slowing and final cessation of respiration appear ultimately to be due to poisoning of the respiratory centre.

Wood points out that irregularity and even cessation of respiration may occur in the early stage of etherisation, and is due to irritation of the nerve fibres of the trigeminus and vagus; this inhibition may be overcome by deepening the anæsthesia and so annulling the reflex. Such respiratory perturbations must of course be carefully distinguished from those due to over-narcotisation of the medulla, which can only occur late and in profound narcosis.

The *heart's action* is at first excited and increased in force; later it quiets down, and may even grow somewhat weaker, though such weakening is always trifling. The *blood pressure* is increased until very deep narcosis is present, when a fall of blood pressure occurs. The peripheral vascular dilatation showing itself in flushing and rubescence of the skin, together with sweating and a roseolous rash, is the cause of this fall in blood pressure.

The presence of the ether rash is pretty constant, but occurs more commonly in women and children. It usually is first seen about the neck and shoulders, but may cover the arms, the chest, and even extend to the thighs. It lasts for a few minutes, sometimes ten or fifteen. It has probably no significance beyond showing the action of ether upon the sympathetic system. Its appearance is usually synchronous with the relaxation of the muscles. Embley† has worked out with

* Embley, *Bio. Chem. Jour.*, vol. v. Nos. 1, 2, 3.

† *Op. cit.*

great care the effects of ether upon the circulatory system. He finds that blood pressure falls if measures are not taken to prevent peripheral dilatation of the vessels, but when ether is given by a closed inhaler (*e.g.* Clover's) this fall is corrected by the limitation of air incident to its use and the maintenance of the tension of carbon dioxide. Ether in high concentration undoubtedly can lead to heart standstill, but the amount of ether in the blood during surgical anæsthesia does not paralyse the heart in a healthy subject. Slowing of the heart does not occur after section of the vagi, although the vagal centre is primarily excited by ether, but ether very rapidly depresses the vagal mechanism so that inhibition of the heart is less likely to occur under this anæsthetic than under chloroform, and indeed does not arise unless the blood pressure has fallen very low, and even then is transitory. The fall of blood pressure under ether is marked, but is due not to enfeeblement of the distributing system, but to the peripheral dilatation. This fact explains why etherised patients are peculiarly sensitive to alteration in the axial position of the body. The "head up" position suddenly effected when the blood pressure has already fallen will cause further depression even to zero. Ether causes great relaxation of the arteries due to its effect upon the peripheral vascular mechanism, since the vaso-dilator centre is slightly affected. Depressor reflexes so common under chloroform and due to stimulation of sensory nerves (trauma) are absent under ether.

Ether appears to act as an irritant to the *kidneys* although healthy kidneys are but little affected by it. Statistics show that pre-existing albuminuria is slightly increased by ether, but that chloroform is more likely to cause albuminuria in those who have presumably healthy kidneys.* The amount of renal derangement is certainly dependent very largely upon the quantity of the anæsthetic which is employed. As less chloroform will produce and maintain anæsthesia when

* On the other hand, Drs. Thomson and Kemp have shown, by experiments on dogs, that albuminuria with lessening of the amount of urine occurs after ether inhalation, but only slight albuminuria without suppression of urine after chloroform inhalation. As I have pointed out above, these results do not agree with those at which I arrived when investigating this matter with the aid of Dr. Levy. I think that probably excessive doses of ether were employed by Drs. Thomson and Kemp, and as a result toxic effects were produced.

given from an efficient regulating inhaler, such, for example, as that of Mr. Vernon Harcourt, it is better in prolonged operations upon the kidneys, or in the case of patients whose kidneys are extensively diseased, to rely mainly upon chloroform. There is no objection in most instances to inducing anæsthesia by nitrous oxide gas and ether, and maintaining it by chloroform or a mixture.

In some patients who are apparently free from bronchial catarrh, the use of ether sets up a profuse secretion of thick tenaceous mucus which hampers breathing. This is especially the case with excessive smokers. For such persons it is well to avoid ether unless atropine has been injected before inhalation, or if the complication is only observed after anæsthesia is established, to substitute chloroform or the A.C. mixture for ether, when as a rule the inconvenience disappears. Before effecting this change, however, the mucus should be sponged out and all signs of respiratory difficulty should have passed off.

Under ether the *muscles* at first become rigid and firmly extended, but later these conditions give place to extreme flaccidity; in some patients the muscles maintain their rigidity much longer than in others, while there is a difference in the time which muscles in various regions take to relax. Snow pointed out that although chloroform produced some degree of muscular relaxation sooner than did ether, yet the most complete flaccidity resulted when ether was used, provided time was allowed for its development. I am entirely in accord with this statement. It is, I think, very common for prolonged muscular rigidity to result from asphyxial conditions, and when these are prevented or alleviated by giving inhalations of oxygen, rigidity under ether rapidly disappears.

Ringer, experimenting on muscle, found that in frogs the vitality of involuntary muscle persisted far longer in the case of ether than in that of chloroform. Peristalsis, although lessened, is not abrogated, even when death is induced by ether.

The *body temperature* is reduced under ether; Kappeler fixes a minimum at 3° C., and a maximum at 1.5° C. (5° — 2.7° F.). Ether increases the secretions, with perhaps

the exception of that of the kidneys. Elimination takes place rapidly and is mainly effected by the lungs.

METHODS OF ADMINISTERING ETHER.

Ether may be given (1) by itself, (2) in succession to other drugs (*a*) after alkaloids, *e.g.* atropine with or without morphine and scopolamine; (*b*) following some other general anæsthetic, *i.e.* nitrous oxide, ethyl chloride, chloroform or its mixtures.

The methods by which ether is given are—

A. By inhalation.

1. A closed inhaler.

2. By an "open" method, itself varying in the hands of different practitioners between a strictly open and drop system, the use of a semi-open inhaler such as Allis', or a gauze and lint covered mask closed in almost completely by an impervious material, as in Dumont's ether mask.

3. By the nasal method.

B. Intra-venous infusion by which saline semi-saturated with ether is allowed to infuse a vein.

C. Intra-tracheal insufflation.

D. Rectal etherisation by ether vapour, or saline or oil containing ether.

E. Intra-muscular injections of ether.

A. BY INHALATION.—I. THE USE OF INHALERS.

The main indications for the successful administration of this anæsthetic are, that the air inhaled be gradually saturated with ether vapour. It cannot be too strongly insisted upon that in spite of all theoretical reasoning to the contrary, asphyxial complications with ether should be carefully avoided. It is best to commence the inhalation with a sufficiently dilute ether vapour so as not to excite laryngeal irritation; the vapour should not escape into the room and impregnate the air breathed by the bystanders; this can only be done by the use of one or other of the inhalers to be mentioned below.

Inhalers devised for the administration of ether by itself, or in succession to other anæsthetics may be classed under

the categories of (1) closed, (2) quasi open. In the first class the patient inhales ether from a bag closed from the air, so that whatever air enters does so through valves arranged for that object. The best type is Clover's portable regulating inhaler. This inhaler has been modified and improved, but in principle it remains the same. The form suggested by Dr. Probyn Williams is probably one of the best, as it combines a wide bore with great lightness and manageability (see p. 151). (2) In the quasi-open type ether is poured upon a sponge or on an absorbent material which is surrounded by some more or less impervious substance; if it is open at the top the patient is able to breathe through the sponge containing the ether. The large mask designed by Dr. Julliard and modified by Prof. Dumont of Bern is the best of these. Ether is sprinkled freely over the inner surface, the external aspect being covered with oil-silk. The Allis inhaler is a nearer approach to a truly "open" method and answers its purpose well. Ormsby's inhaler is a compromise between the two classes, as in its use the patient respires through the etherised sponge into a closed bag.

Clover's portable regulating ether inhaler (fig. 24) consists, as reference to the figure indicates, of a dome-shaped ether receptacle pierced by a central shaft, into which are adapted (1) a tube bent at right angles, carrying the indiarubber bag into which the patient breathes, and (2) a metal tube which serves for the attachment of the face-piece, and has an indicator attached to it which records approximately the relative proportions of the ether and air respired. There is a tube with stopcock for inflating the air-cushion which rims the face-piece and helps it to fit the face accurately.

The ether reservoir, and water chamber which surrounds it and maintains it at the desired temperature for evaporation, rotate upon the metal tube shown in the diagram with the figure "2" upon it. This fits accurately in the mount of the face-piece and the projecting indicator is received into a slot in the mount. The instrument is constructed so that no liquid ether can escape in whatever position the inhaler is placed.

Method of using ether inhalers ("Clover" type).—A face-piece of an appropriate size having been selected, and two ounces of ether placed in the reservoir, lasting approximately half an hour, the air-bag is removed and the indicator turned to O. The patient is then directed to inspire freely, and the face-piece applied gently but firmly. Uniform pressure is well borne, while hard pressure if unequally distributed will not be tolerated. When the patient has taken two or three deep breaths, the air-bag is filled by placing it in position as the patient expires the air from his lungs. The inhaler

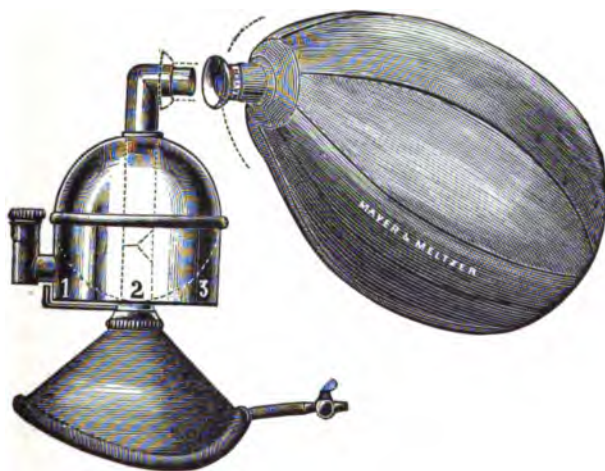


FIG. 24.—Clover's portable regulating ether inhaler.

being placed over the patient's face, the patient now breathes in and out of the bag. The ether reservoir is next moved so that the indicator points to the figure "1" and the patient then breathes about one-fourth ether and three-fourths air. A few breaths of such a dilution of ether will accustom the larynx to the irritating vapour, and so obviate coughing, spasm, and the wretched feeling of suffocation which ensues upon presenting a strong ether atmosphere at the commencement of an inhalation. This tolerance achieved, the ether reservoir is rotated till the indicator points to "2," and the patient then inhales, roughly speaking, half ether and half air. If this strength of vapour does not distress him, the

indicator, by further rotation of the ether chamber, can, after a few seconds, be made to point to "3" (one-fourth part air, three parts ether) and then to F (full ether).

The variation in size of the pupils during ether narcosis is an uncertain guide. They are not uniformly influenced by the anæsthetic as in the case of chloroform, and so have no common ground of comparison. When full anæsthesia is established the pupillary reaction to light will be less active and the size of the pupils will remain fairly constant, tending to dilate when the anæsthetic is pressed. Excessive doses produce a slowly reacting pupil and wide dilatation. The same result follows when much shock occurs with loss of blood and the anæsthetic has been given freely. Although in many instances increasing the depth of narcosis dilates the pupil and renders the light reaction sluggish, while lessening the degree of narcosis causes the pupils to contract slightly, these phenomena are not absolutely constant; some pupils, especially in old persons, remain contracted, while others are moderately dilated and show little change. In moderate degrees of narcosis the pupils will be seen to change in size synchronously with respiration. It is never well to push the ether to a degree in which light reflex is almost abolished. The younger the eye the more active are the pupillary reactions. In testing all eye reactions it is important to avoid frequent and rough handling of the conjunctivæ and to compare the two eyes, since one eye rapidly loses its reactions unless allowed to be quiescent.

With the assistance of Mr. Upcott Gill, who was my chloroform clerk, I examined a large number of patients, and the statements made above represent the conclusions at which I arrived. It may be added that as a rule the advent of cyanosis was associated with some pupillary dilatation.

The patient will, in from ninety seconds to two and a half minutes, be completely unconscious and ready for operation. The muscles are rigid at first but subsequently grow flaccid; as a rule consciousness is lost as soon as this rigidity is present, but the profound narcosis required for many operations only supervenes with muscular relaxation. Any cyanosis or respiratory embarrassment will prolong the period of rigidity. I have repeatedly produced relaxation

at once by allowing the patient to inhale oxygen. Some persons require more ether to render them insensible, and those who persistently resist taking the anæsthetic by holding their breath, or by taking the shallowest breaths consistent with life, will delay the onset of unconsciousness much longer. These persons also, since they voluntarily semi-asphyxiate themselves by repressing respiratory movements, suffer great additional discomfort from the feeling of suffocation they induce.

As soon as complete anæsthesia is thoroughly established, that is when the conjunctival reflex is abolished, the indicator may be brought back to "2" by turning the ether reservoir round and kept there until the operation is over. It may be necessary in warm weather, and in the case of prolonged operations, to renew ether in the receiver. This is easily done by removing the inhaler from the patient's face, loosening the stopper, and pouring in a further supply.

The patient will, during a protracted operation, require the inhaler to be taken off his face every sixth breath or so, in order that he may take a few inspirations of air. The necessity for this will be readily recognised by any cyanosis apparent in the face or ears, and by the character of the respirations and of the pulse. It should be carefully borne in mind that the amount of an anæsthetic required to produce narcosis is much greater than is needed to maintain that condition. Also the degree of narcosis must be varied, in correspondence with the region of the body upon which operative measures are being pursued. For operations upon the abdomen, the genitals, the rectum and perineum, a deep narcosis is necessary, and must be maintained throughout the operation, otherwise movement and vomiting result. To test the degree of narcosis, although the size of the pupil is an unreliable guide, it may be noted from time to time to see whether the light reflex remains keen and the corneal reflex is returning. In deep narcosis, that is short of overdosage, the lid reflex is quite abolished, the pupil may be semi-dilated, the ocular movements sluggish and the light reflex slow. Fixation of the eyeball seldom, if ever, occurs in ether narcosis unless the ether is administered with oxygen, as in that case the depth of the narcosis may be very profound.

The respiration is often hurried in light but slower and more shallow in deep narcosis while the breathing is gasping. The ruddiness of early etherisation gives place to pallor with slight duskiess after prolonged or profound etherisation. The advent of returning consciousness is commonly shown by the patient's efforts at swallowing, the initial act of the physiological mechanism of vomiting; by return of conjunctival reflex and by alteration in respiratory rhythm. Frequently also pallor with sudden pupillary dilatation may occur. In all cases it must be remembered that the dilatation



FIG. 25.—Sheppard's angular adjuster.

of the pupils, variations in respiration, and circulation, may be reflex and must not be mistaken for ether effects. It is this fact which convinces me that students should avoid consulting the pupil in ether narcosis until they have acquired a thorough mastery of the cycle of ether narcosis as a whole.

When it becomes necessary to anæsthetise the patient in the prone or semiprone posture, a useful addition to the Clover's regulating ether inhaler is the angular adjuster figured above. This useful contrivance is the invention of the late Dr. Charles Sheppard (see fig. 25).

This inhaler was intended by Mr. Clover for the admin-

istration of ether alone, but it has been adapted for the exhibition of that vapour in conjunction with nitrous oxide gas, and Mr. Clover himself, writing in 1877, says, "by connecting the bag with a supply of nitrous oxide it forms a tolerably efficient substitute for the gas and ether inhaler" (see p. 170). Thus by attaching a stopcock in the metal bent piece to which the bag is attached, gas can readily be admitted into it by a long indiarubber tube coming directly from the gas bottle.



FIG. 26.—Dr. Probyn Williams' ether inhaler (wide bore).

It is often urged as an objection to Clover's regulating inhaler, that the lumen of the tube through which the patient has to inspire is too small to permit of unembarrassed respiration. As a result the patient tends to become cyanosed and suffers from feelings of impending suffocation.* Sir Frederic Hewitt,† who has carefully considered this question, attaches great importance to the presence of a wide bore in

* This question is fully discussed by Sir F. Hewitt, *Lancet*, March 30, 1901. In this paper is described Sir F. Hewitt's large-bore inhaler.

† "Anæsthetics and their Administration," 1912, pp. 348 *et seq.*

the inhaler, and his apparatus provides such an increased size of air way.

Dr. Probyn Williams, whose inhaler is figured, carries out in a simple way the modifications which Sir Frederic Hewitt regards as essential.

Whether this is not a theoretical rather than an actual objection is, I think, open to question. The patient actually obtains his ether and air from the face-piece, and provided the tube to the ether supply and bag is not less than the diameter of the trachea it is difficult to understand how when the content of the face-piece is gradually emptied by inspiration there should be any impediment to breathing such as would cause a *besoin de respirer*. When a small bag is used there is no doubt that such a result may occur, but in that case it is the size of the bag rather than the diameter of the bore which is at fault. Clover appears to have accepted this view in constructing his inhaler.

Ormsby's inhaler.—It consists (fig. 27) of a zinc face-piece with cushioned rim capable of being inflated through a small tube guarded with a stopcock. The face-piece is provided with a valve, which can be opened at the pleasure of the administrator; at the top of the face-piece is a cone-shaped wire cage, covered externally with red rubber and leading into a rubber bag covered by a loose net which prevents its undue expansion. In the wire cage a sponge is placed, and upon this half an ounce of ether is poured. Various modifications of the inhaler are in use.

In fig. 28 is shown Mr. Carter Braine's modification of Ormsby's inhaler by which a succession, A.C.E., ether, chloroform, can be given. It is constructed throughout of metal, nickel-plated, all parts are easily accessible, and can be rendered aseptic by boiling. The air-valve is a free one and is numbered with figures, as on Clover's inhaler. The cage being rigid and made of open work is incompressible, permits of free respiration, and cannot gradually become constricted with use. The respiratory bag is 12 inches in diameter, so that there is no need of netting. The cage bearing the sponge and respiratory bag fixes on the face-piece with a bayonet catch. An extra dome has been constructed of metal and freely perforated with air-holes at its extremity;

this also fits on to the face-piece with a bayonet catch and takes the place of the other dome. This attachment is very useful for the administration of the A.C.E. mixture or for ether when plenty of fresh air is necessary, as in the case of young children and of the very feeble. The administration can be begun with the A.C.E. mixture, and then the A.C.E. dome detached when required, the other dome applied in its place and the administration continued with ether. Should it be desirable to change the anæsthetic to chloroform, the tube from a Junker's inhaler can be applied to the



FIG. 27.—Dr. Ormsby's ether inhaler.

projecting tube of the A.C.E. dome, and the chloroform apparatus is thus complete. Should the entry of air be too free then some of the holes at the extremity of the dome can be occluded with the hand or by packing with the cotton-wool.*

METHOD OF USING ORMSBY'S INHALER.—The sponge is wrung out in warm water before use, but if, as Carter Braine suggests, an open sponge be loosely packed into the cage and only small quantities of ether are poured on at a time, this is unnecessary. The valve should be open at first and

* See *Lancet*, December 3, 1898, p. 1,488.

gradually closed as the larynx grows accustomed to the ether, and the inhaler should be held lightly over the face and only fitted closely as toleration of the ether becomes established. When fresh ether is required it can be either poured through the tube designed for this purpose, or as I think is preferable, thrown directly upon the sponge by removing the inhaler from the patient's face and inverting it. Care must be taken that there is no excess of the anæsthetic, which may trickle over the face. It is well to have a second sponge in readiness in case the first one freezes. The second one can conveniently



FIG. 28.—Carter Braine's modified Ormsby's inhaler, the "extra dome" and the air-pad of the face-piece.

be kept in warm water within reach. Unless care is taken to give the ether gradually by leaving the valve freely open at first and by putting on only small quantities of ether (half an ounce or less) at a time, the patient experiences great distress from a feeling of suffocation. This and the liability of the sponge to freeze are the two great objections to this inhaler, but as the description above shows, these can to some extent be overcome by care and expertness. Another objection to it lies in the fact that a gradual increase or lessening of the quantity of ether given cannot be so well effected as in the case of Clover's inhaler.

Rendle's mask (fig. 29) is a convenient pattern. It is made of leather and contains a thick flannel cap which is allowed to extend beyond the lower edge and be folded back so as to rest upon the face when the mask is applied. At its summit a sponge is placed, upon which ether is dropped in small quantities, a drachm or two from time to time. Subsequently half an ounce may be used as required. A free air-way is obtained by perforations at the summit of the cone. If the sponge freezes it must be replaced by another which should be ready at hand as in the case of the Ormsby's inhaler.

This inhaler is also made of celluloid at the recommendation of Dr. Silk, and in this form it is both handy and clean.



FIG. 29.—Rendle's mask and flannel cap in cone.

In the use of this mask care must be taken that too much ether is not poured on, otherwise it soaks into the flannel and may drain over the patient's face. The cone is at first held an inch or so from the face and gradually brought nearer until it fits closely. It is only lifted to renew the ether or to prevent cyanosis.

Open inhalers.—The simplest form is a towel or piece of millboard rolled in the shape of a cone with a sponge placed at its summit. Ether is poured upon this and renewed from time to time. This plan is not satisfactory, and unless in exceptional cases, when there is great asthenia or collapse, it is difficult to produce complete anæsthesia with it.

Allis' inhaler.—This is I think the best "semi-open" ether inhaler; for while it can be used for chloroform, the A.C.E., or other mixture, it is always available when it is

desirable to give ether largely diluted with air. I have used it for several years and have found it most valuable. It possesses the disadvantage common to all instruments of its class, that much ether is wasted, and becomes diffused through the room to the discomfort of the operator and his assistants. It consists, as can be seen from the woodcut, of a metal frame so arranged that a flannel or domett bandage can be stretched



FIG. 30.—Allis' ether inhaler.
(The inhaler is represented upside down in the figure.)

across and across. The outside is covered with a leather case, which being prolonged below the metal serves as a well adjusting face-piece. Fresh additions of the anæsthetic are dropped from time to time upon the bandage from above. This may be done from a drop bottle, or the inhaler may be inverted and a few drachms poured in from below. Its use needs no full description. At first a comparatively weak vapour strength should be employed ; subsequently the requisite concentration may be rapidly obtained by pouring on more ether.

The bandage must be removed and the inhaler carefully cleansed after use and a fresh bandage applied. These inhalers can be made up of whatever size is required.

THE ADMINISTRATION OF ETHER BY ITSELF.

The effects of ether inhalation will vary considerably according as the patient is narcotised rapidly or slowly. Slow etherisation possesses no advantages under ordinary circumstances, and is indeed positively harmful by prolonging the stage of delirious excitement. In conditions of extreme shock, or asthenia after great loss of blood, or ensuing upon a prolonged illness, it may be necessary to proceed with extreme caution and to employ small quantities of the anæsthetic, but this does not affect the general principle enunciated above.

The inhalation.—The actual administration is carried out either by the use of an inhaler or by an open method, but before considering these methods in detail it will be well to present a general account of the phenomena met with during the period of induction.

The patient being placed in the supine position and his clothing loosened, his mouth is examined for artificial teeth or an obturator, and if such are present they are to be taken out and ether administered by one of the above methods. Although the supine position is best, yet for operations for the removal of the teeth, or upon the post-nasal space, the patient may be allowed to be propped in a sitting posture, or be seated in a chair.

When the patient first breathes ether vapour, he catches his breath, may cough and resist the ingress of the vapour. The resistance will be in proportion to the strength of the vapour used. A few inspirations will render him dazed, the face will flush, the eyes grow suffused, and the breathing will become rapid. The pulse in this stage is full, softer than natural, and accelerated. Although stupefied, the patient can still perform certain voluntary acts, *e.g.* putting out the tongue if loudly desired to do so. The feeling of suffocation which was at first experienced now gives place to one of exhilaration, the dyspnœa disappears, and the respirations are full and deep. Formication and tingling are felt in the hands and feet. The pupils usually contract in this stage. The exhilaration, however, soon passes into a condition of delirious excitement. Bert denied that true excitement occurs,

believing that progressive loss of muscular power supervenes. The disorderly movements commonly put down to excitement of delirium are, he thought, to be explained as *une sorte d'anarchie cérébrale*, the guiding centres being in abeyance. In whatever way we regard these movements, they certainly appear to be the result of temporary delusions. Thus, military men may, in this stage of etherisation, shout words of command ; while those inclined to pugilism may attempt to box with the bystanders. The respirations and heart's action are considerably accelerated ; the skin grows moist, the face dusky. Soon a period of quiet follows, and it should be the aim of skilled etherisation to curtail as much as possible the stage of excitement. In the succeeding quietude the limbs stiffen, the muscles grow strongly contracted and firmly set, the whole body becoming rigid. Breathing may be hampered by the rigidity of the thoracic muscles and needs careful watching at this time. Should the respirations stop, it will be necessary to lift the inhaler and firmly compress the chest two or three times and so encourage respiration. The pupils dilate now and the skin becomes bedewed with perspiration, while a roseolous rash appears in patches about the neck and chest. These patches coalesce. In several hundred cases examined by me it was generally present in some degree, although often so transient and slight as to be easily overlooked. The pulse resumes its normal rate, and although soft, yet remains regular and somewhat more forcible than before inhaling the anæsthetic. The blood pressure is raised, but falls nearly to the normal as anæsthesia is fully established. Now ensues the stage of muscular relaxation. The patient lies absolutely insensible to all external impressions, with his muscles perfectly flaccid. The **lid reflex** is **lost**. The breathing slows although it keeps quicker than normal, and is much more shallow. At this time anæsthesia may be taken as complete, and operative measures may proceed.

The depth of narcosis varies according to the amount of the anæsthetic given. For brief operations not involving a very sensitive area a light narcosis is to be aimed at, and in every case as little of the anæsthetic should be given as is consistent with the necessities of the operation. It must

always be borne in mind that the severity of the after effects is dependent upon the amount of the anæsthetic inhaled, and the toleration of the patient for the anæsthetic. When once true anæsthesia is obtained the patient requires comparatively little ether to keep him insensitive.

The recovery.—The time which elapses between the moment when the anæsthetic is withdrawn from the patient, and when he is conscious and has resumed control of his actions, varies in length in different cases. Generally speaking, the duration of this period of "recovery" is longer directly in proportion to the amount of the anæsthetic taken, and inversely to the physique of the patient. Some persons simply sleep off the effects of the ether, are often a little sick and vomit some mucus or clear fluid smelling of ether. Others become excited, going through a period of excitement similar to that which many persons experience in "going under" ether. A few, especially the neurotic, appear almost maniacal for a time. The maudlin and the jocular phases of emotion may reveal themselves and call for only passing mention. Others, especially when a severe operation has necessitated the inhalation of a large quantity of the anæsthetic, reveal a profound stage of collapse, are cold, motionless, with hurried weak breathing and feeble pulse. This is often the result not only of surgical shock but of nerve-centre exhaustion consequent upon over and excessive ether stimulation. Certain persons commence to vomit immediately the etherisation has ceased, and continue to do so for hours with more or less frequency. All the above conditions may be slight and transient, or may need careful and suitable therapeutic treatment. No patient should be left unattended after taking ether, lest through a malposition assumed in a semi-unconscious movement his respiration become impeded and suffocation ensue. Another danger is from vomiting during recovery, the vomitus entering the air passages and choking the patient. Several deaths have ensued from syncope occurring in unattended patients who have sat up suddenly during recovery. A more insidious danger during this period is chilling of the patient. Often he is removed from a heated operating-theatre, or room, and carried into an improperly warmed ward or

bedroom, with the result that bronchitis, or even bronchopneumonia supervenes, and this is ascribed solely to the effects of the ether or a "dirty inhaler." In all cases the patient should be carefully wrapped in blankets, hot water bottles placed in suitable positions, care being taken that their heated surfaces cannot touch and burn the skin—a not infrequent danger—while he should be so arranged that the head lies low, the face turned to the side. An attendant should be close at hand to restrain undue movements, uncovering of the body, and to help in the case of sickness. Special treatment required for more grave complications and after effects are considered below.

Open methods of producing anæsthesia by ether.—The phrase "open ether administration" covers a number of procedures which are not strictly "open" as masks are sometimes almost covered with impervious material and in some cases inhalers even are adopted. It is proposed to deal with the usual plan of employing the open ether method and to supplement it by describing some of the many modifications which experience has suggested.

2. THE OPEN METHOD OF ETHERISATION.

In every case atropine, gr. $\frac{1}{100}$, or some suitable dose should be injected one hour before the inhalation. A mask* such as that used by Mr. Mayo, a Skinner, or a Schimmelbusch is sterilised and twelve to eighteen plies of gauze are laid so that they extend on each side and below the chin while a single thickness of lint is placed over them and the whole is fixed in position by the ring or hinged attachment. A small hole to serve as a window is cut in the lint on the side of the mask which will remain uppermost throughout the narcosis. The head should always be turned to the side away from the seat of operation. The ether supply can be obtained by a dropper such as the one figured below (fig. 31) or an ordinary bottle can be fitted with a cork in which two slots have been cut. I have my ether placed in $\frac{3}{4}$ iv. bottles which, once opened, are never

* The plan suggested is that which the author, after many trials of various systems, has elaborated and now usually employs, although Dr. Ferguson's method described below possesses undeniable advantages.

kept for a subsequent occasion. In one of these slots a few strands of wick thread folded together are passed so that it falls to the bottom of the bottle and a free end hangs for one-quarter inch out of one of the slots in the cork. The other slot admits air into the bottle. The cork must not be pressed in too tightly unless air can enter freely, or the ether will not readily drop. The patient's eyes are protected by a pad of lint and as soon as he is sufficiently dazed by the ether a few drops of castor oil are dropped into them so as to prevent the ether



FIG. 31.—Jackson's ether dropper.

vapour setting up conjunctivitis. The cheeks and chin can be protected if necessary from ether irritation by vaseline, oil, silk, or a folded towel, but unless the ether is poured on too rapidly this precaution is seldom required. A ring* made out of spongiopiline with an aperture taking the mouth and nose answers very well as a protection against ether irritation and also prevents the possible bruising of the face by the metal mask.

* I see that Sir Frederic Hewitt adopts a similar plan, but uses a gauze pad, which is possibly open to the objection that it is readily permeable to any ether leaking upon it.—"Anæsthetics," 4th ed., p. 339.

The mask being placed in the best position is held by the left hand which also supports the mandible, while the right hand holds the drop bottle. This is inclined to such an angle that the ether falls drop by drop on to the gauze left exposed

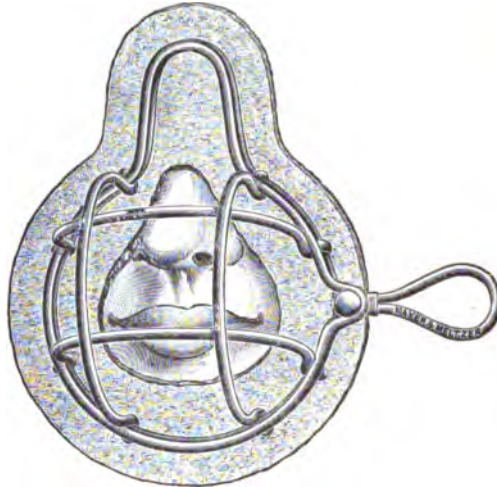


FIG. 32.—Showing spongiopiline ring on the face with Mayo's mask without gauze resting *in situ*.



FIG. 33.—Side view of Mayo's mask.
(Shows Mayo's mask with gauze spread over it.)

by the window cut in the lint. At first the drops should fall at fairly long intervals, but as soon as the patient becomes accustomed to the vapour their frequency can be increased. At no time should the lint become soaked, as this prevents evaporation except perhaps in very hot weather, while it also checks the escape of the patient's expirations, so causing him

inconvenience, and may occasion cyanosis. The duration of induction is about ten minutes, but weakly persons go under more rapidly, while vigorous muscular individuals often require longer time for the induction.

Nervous people by holding their breath and taking very shallow respirations can delay induction. This is usually due to an unwise pushing of the anæsthetic in the initial stage and is corrected by lessening the rate of dropping and by pushing forward the mandible as soon as an inspiration has commenced, and so deepening and prolonging the intake of air and vapour. Children as well as nervous persons often give trouble in this way, and it may be requisite to give a few inspirations of the A.C. mixture on another mask having only a single layer of lint in order to start the induction. Under no circumstances should chloroform or its mixtures be dropped on the ether mask with its many folds of gauze, otherwise a high concentration of vapour will remain in the mask, and as breathing deepens an excessive dose will be inspired. After morphine also the breathing is apt to be slow and shallow, and similar measures are commonly called for to save a needless expenditure of time and to obtain a satisfactorily deep narcosis.

Usually there is but little struggling or excitement, and, provided atropine has been given, no salivation or undue secretion of mucus. If this preliminary has been omitted there is often a free flow of both which hinders quiet breathing. Cyanosis is absent unless some interference with respiration has occurred, although an attempt at a rapid induction by pouring on the ether instead of dropping it may set up cough, spasm, breathholding with cyanosis. Prolonged narcosis when ether has been given freely will in the later development of the period of maintenance also cause cyanosis, and this, at the period mentioned, is usually a sign of overdosage calling for removal of the mask and free ventilation of the lungs with air, or better with oxygen. Edentulous patients with muscular pendulous lips so commonly found associated with the loss of teeth and shrinking of the alveolar processes, may give trouble as soon as consciousness is lost. The lips are sucked in during inspiration, forming a valve which while it permits expiration allows little of air or ether vapour to enter. The use of a

dental prop between the gums in the front of the mouth or a gag placed at the side will remedy this and allow the requisite depth of narcosis to be obtained. If the covering of the mask becomes too wet, the supply of ether should be withheld and a towel covered by the warm hands may be placed for a minute or so over the wetted area until evaporation has taken place. This if properly done will not interfere with respiration. However, should cyanosis or even duskiness co-exist with an excessive ether supply it is best to lift the mask until the normal colour has returned and then proceed more cautiously with the dropping method. It has been estimated that the concentration of the ether vapour given from a closed inhaler is about thirty per cent., whereas that presented by the open mask is never more than twelve per cent., and is usually less than this. In an open ether method the material used for the evaporating surface is a matter of importance. When "spread" is rapid and the use of a fine meshed material allows rapid air movement through the mask coverings evaporation is accelerated. This difference in concentration of the ether atmosphere inhaled accounts for the lighter character of the narcosis under an open method, but since the breathing appears to be more free and lung ventilation more ample during its use, the net result is, that although less ether enters the air passages in a given time, yet its entrance being more easily obtained, a very large amount will eventually enter the circulation and a sufficient depth of narcosis will be obtained. To avoid the unnecessary waste of time during induction with the associated discomfort to the patient the open method may be supplemented, and I think usefully, by the employment of some preliminary system of anæsthetisation which accelerates the induction and assists to deepen the initial narcosis, an important matter when the operation is one requiring complete relaxation of the muscles about the area of operation and absolute immobilisation of the patient with suppression of such reflexes as disappear only during deep narcosis. It must, however, be remembered that many visceral reflexes, those connected with respiration and even those associated with skin areas of great sensitiveness, cannot be abrogated unless the life of the patient is to be placed in jeopardy. The usual depth of narcosis obtained by an open ether method is one

consistent with "maintenance" as opposed to "induction," and hence the methods to be specified are useful if not essential for the best results to be gained when the open method is pursued. The induction when giving open ether throughout and without the preliminary use of alkaloids, being long and involving a continued period of light narcosis, is often complicated by vomiting and the patient is apt to doze, so that precautions taken to prevent the former annoyance, and the jaw movements mentioned above to obviate the latter, are commonly required.

For deepening the narcosis the preliminary use of scopolamine, morphine, and atropine is excellent, although these drugs also tend to make the patient breathe shallowly, restricting pulmonary ventilation, hence it is necessary to take measures to ensure free breathing. The use of these drugs materially lessens the quantity of ether requisite for obtaining even profound anæsthesia, but as their action persists for some hours it is essential that overdosing with ether be avoided, with its result, more or less prolonged and deleterious post-operative anæsthetic effects. The patient must be carefully watched until he has completely come out of the deep stupor sometimes caused by these drugs. To hasten induction various methods, considered in detail in other sections, may be adopted. Thus nitrous oxide or ethyl chloride followed by ether from an inhaler, or chloroform or one of its mixtures, *e.g.* the A.C., the A.C.E. (pp. 169-175), may be employed to commence induction. Although giving chloroform during the induction period is obviously open to criticism, yet when a regulating inhaler is used the danger is minimised if not obviated. Indeed, after morphine and scopolamine, it is wise to adopt chloroform or a chloroform mixture as an introducer to the ether to obviate the rousing effect of the latter anæsthetic upon the patient bemused by the drugs.

The following method due to Dr. Ferguson, of East Orange, New Jersey, U.S.A., who was one of the first to introduce and systematise the open ether method, is one of the best. Dr. Ferguson was good enough to demonstrate his method at University College Hospital, and convinced me of its value.

FERGUSON'S INHALER FOR THE ADMINISTRATION OF ETHER BY THE OPEN DROP METHOD.*

The apparatus consists of a wire frame, fig. 34, so constructed that over the convex portion, A (figs. 34 and 37), several layers of surgical gauze may be stretched and held taut in position by the flexible wire, E (fig. 35), as illustrated in fig. 37. The whole is covered with a Canton flannel hood (fig. 36), so made that it can be drawn up closely against the flexible face wire, B (figs. 34 and 37), and gathered on top so as to leave an opening, G (figs. 36 and 37), three-fourths of an inch or an inch in diameter. In this way two

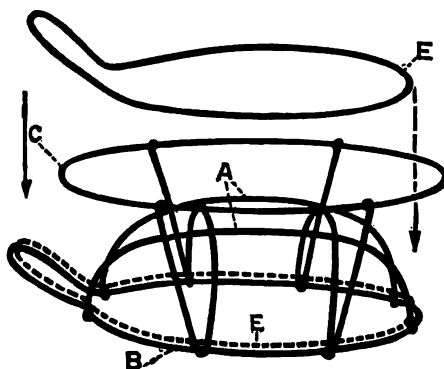


FIG. 34.—Ferguson's mask with parts separate.

chambers, K and M (fig. 37), are formed, in the upper of which the ether and air become mingled while the patient inhales the mixture from the lower one.

Directions for Use.—Remove the flexible retaining wire, E (fig. 34), and then *fit the wire frame, A, B, C, E, accurately to the face of the patient*, so that no air can enter between the inhaler and the face. As the face wire, B, and the convex portion, A, are made of very flexible wire, the fitting can be easily done by bending the wire between the fingers. Further, if the face be long and narrow, the inhaler may be lengthened by pulling it out in the line of its major axis. If the face be broad the instrument may be widened

* See Dr. Ferguson's article on the inhaler in *Journal American Medical Association*, Dec. 30, 1905. The description in the text is given mainly in Dr. Ferguson's own words.

by pulling it out in the line of its minor axis. After the frame has been thus fitted, place over the convex portion, A, several layers of surgical gauze of such size as to completely cover the convex portion, A. Then insert the flexible retaining wire, E, and press it home, thereby stretching and retaining the gauze.

The number of layers of gauze to be used is dependent upon the size of the mesh of the gauze, usually ten layers.

After the gauze has been adjusted, cover the whole frame with the Canton flannel hood. This is done by first inserting the wire loop *which comes over the nose* through the small opening made for it, and then drawing the rest of the hood over the frame. The lower part of the hood should be made to fit closely and accurately around the face wire, B, without allowing it to impinge upon the large opening of the inhaler, which comes next to the face. The inhaler will thus fit

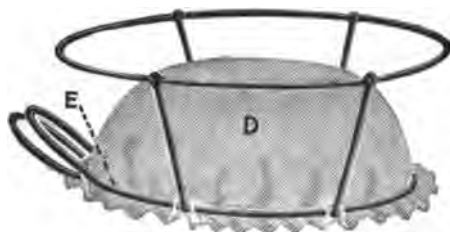


FIG. 35.—Mask with gauze in position.

closely to the face, and, at the same time, the edge of the bag will form a cushion which will prevent any harsh contact of the wire with the face.

The apparatus, now ready for use, is laid gently over the face of the patient. If properly fitted, no air will pass between the face of the patient and the inhaler, but all air will go in and out through the opening, G (figs. 36 and 37). Allow the patient to breathe through the inhaler, in order that he may feel that his respiration is not embarrassed, then allow a drop of ether to fall through the opening, G, on to the gauze, D; in two or three seconds allow another drop to fall, and repeat this process several times. Soon it will be found that the mucous membrane of the respiratory passages is sufficiently anæsthetised to be tolerant of the ether, and then the dropping may be more frequent. The rapidity of the dropping must be learned by experience. Usually, after the passages have become tolerant of the ether, about two or three drops a second will suffice to put the patient in a state

of surgical anæsthesia in from two or five minutes, this being accomplished without any manifestation of the so-called secondary degree, except, possibly, a fixation of the chest. If this occurs, it is not an alarming symptom, and the inhaler should not be removed but kept upon the face and the ether continued. Soon the respiration will begin again, or it may be hastened by gently compressing the chest or abdomen. To maintain the surgical anæsthesia thus produced, the dropping should be continued; as the anæsthesia proceeds and deepens, the dropping may be less frequent. The amount of ether necessary can be determined by an intelligent watching of the operation. This is the care of the anæsthetist, not because of his interest in the operation *in se*, but in order that he may conduct a better anæsthesia. By thus keeping an eye on the operation and noting whether the reflexes remain abolished and the muscles relaxed, the dropping may be so regulated as just to maintain surgical anæsthesia, from

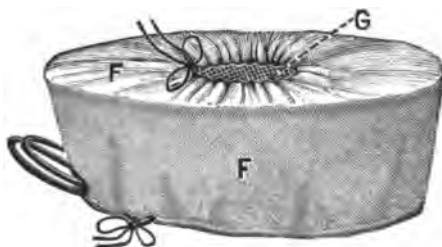


FIG. 36.—Complete with "Canton" flannel hood.

which the patient will recover very quickly as soon as the inhaler is removed from the face.

It is recognised that alcoholics and those addicted to the opium habit take ether badly, but even with them excellent results have been obtained with this instrument.

For adenoid, mastoid and similar operations, in which it is necessary to keep the patient's head on one side, a cover closed on top and having the opening in the side should be employed.

Dr. Ferguson points out in the article to which reference is given that the less precise methods waste ether, are apt to cause irritation of the skin, and by over-wetting of the gauze to render the inhaler at once impervious to the patient's expirations and poorly adapted for an evaporation surface. In the plan detailed above (p. 160), some of these defects are obviated

by manœuvres similar to those Dr. Ferguson has suggested, while it obviates the need of a rather special form of mask. At the same time it must be remembered that Dr. Ferguson's mask is probably the best one yet devised, and with it the intelligent anæsthetist will get results far superior to any which will result from using the extemporised masks made out of a Skinner or a Schimmelbusch and layers of gauze. Undoubtedly the common methods give rise to great waste and do not ensure that perfect disposal of expirations so essential to the welfare of the patient.

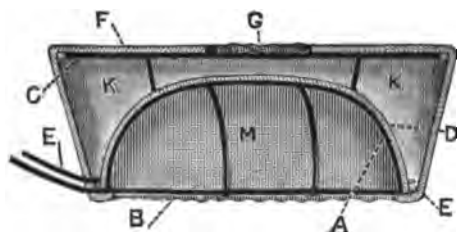


FIG. 37.—Showing section of mask after final adjustment.

ETHER IN SUCCESSION TO NITROUS OXIDE.

At the present time the adoption of an "open" method of giving ether is very common; whether this is the best method in all cases is considered later. Even when an open method is adopted it is often wise to shorten the induction by giving the gas and ether sequence, and replace the inhaler by the open mask when anæsthesia has been established. The best methods of effecting this are given in the following section.

Clover's method.—This plan, which at the time of its first adoption revolutionised the practice of ether narcosis and rendered ether at once a safe and satisfactory anæsthetic, is based upon the principle that the patient is able without discomfort to inhale nitrous oxide, and when unconscious, ether vapour in increasing strength is mixed with the gas, and finally ether vapour inhaled by itself. In this way there is no break in the continuity of the narcosis and no sudden transition, *i.e.* nitrous oxide gas first, then this anæsthetic mixed with ether vapour, and finally ether vapour alone.

Many forms of apparatus have been suggested since Clover's first one was designed, but none have, I think, any material advantage over the original, except perhaps those in which the bore of the air passage is enlarged.

Clover's large gas and ether inhaler.—The present form is the same in principle, but has been modified and improved. It is shown in the diagrams given below. The gas supply is derived from steel cylinders (fig. 38), placed horizontally, and the gas traverses an indiarubber tube to the

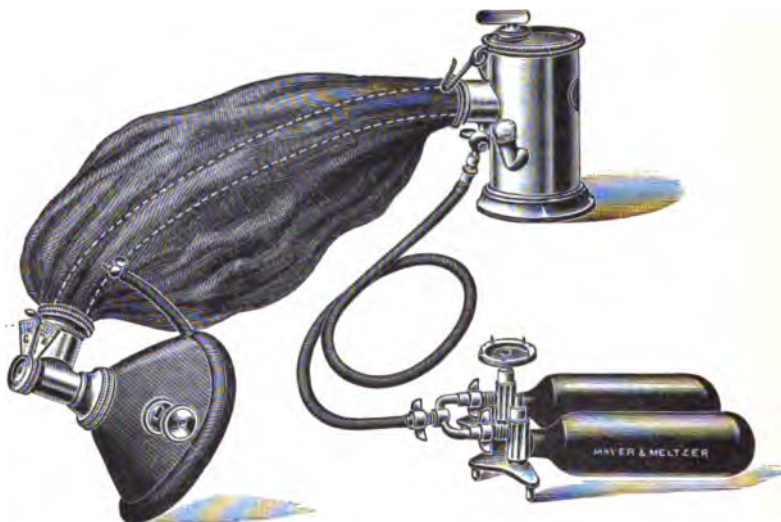


FIG. 38.—Apparatus for the nitrous oxide and ether sequence.
In the figure the ether tap is turned on, but the N_2O tap is turned off.

ether chamber. This is shown in fig. 38. The apparatus is so arranged that gas can be given alone or with ether. By turning a tap the gas passes directly into the receiver containing ether, and having traversed it and passed over the surface of the ether, escapes into the face-piece along a tube which traverses the Cattlin's bag. The amount of admixture of gas and ether is regulated by a tap, which opens the two apertures. The whole apparatus is light, and is suspended by a hook from the administrator's buttonhole.*

In this apparatus the gas supply is controlled by the foot,

* The apparatus is made by Messrs. Mayer and Meltzer, of London.

which, placed upon the foot-piece, rotates it from right to left to turn the gas on, and from left to right to turn it off. When the cylinders are placed horizontally, the exit valve is so situated that a foot-piece placed on the long axis of the bottle regulates the supply.

Fig. 39 shows a section of the ether chamber. The ether and gas supply taps are supposed to be open, and the arrows

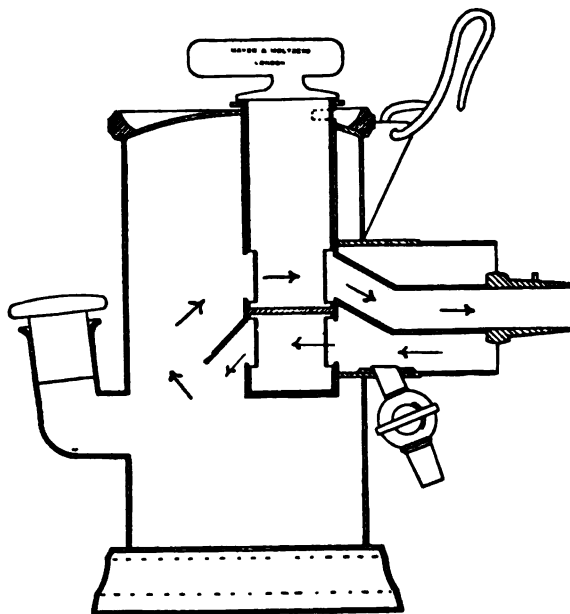


FIG. 39.—Section of ether chamber of Clover's inhaler.

The arrowheads indicate the directions in which air or gas passes into the ether container, and having traversed this passes out impregnated with ether vapour to the patient.

indicate the route by which the mixture of the anæsthetics passes from the chamber into the central tube and Cattlin's bag.

To avoid the obvious difficulty of cleansing the older forms of the inhaler, Messrs. Mayer and Meltzer have constructed for me the apparatus figured below (fig. 40). In this all the parts are easily disconnected and the metal parts can be boiled while the rubber portions can be carefully sterilised with carbolic acid lotion (1 in 20). A com-

parison of the figures will give a clearer idea of the inhaler than verbal description.

The advantages of this apparatus are :—

The absolute control the administrator possesses over the strength of vapour with which he is working ; thus, he can commence the administration with pure gas, then permit some gas to pass over the ether, and by degrees increase the strength of the vapour to full ether without exciting spasm or coughing.

Its great simplicity and portability. It has been termed

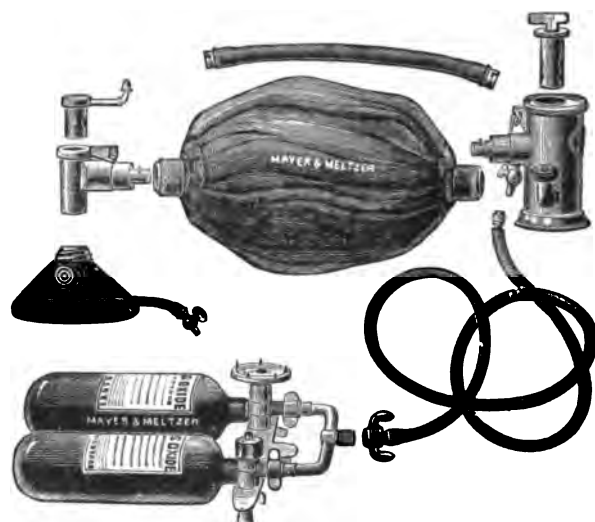


FIG. 40.—Dudley Buxton's improved ether inhaler.

The parts are shown separated from each other, thus indicating how they can be cleaned and sterilised before use. The tube shown above the bag passes through it, and yokes with the other reservoir, and the metal mount forms the face-piece.

unsightly and cumbersome, but no one familiar with its use would find it either the one or the other.

- The same apparatus is equally satisfactory when ether or even nitrous oxide gas has to be administered unmixed, as with care and proper cleanliness the rubber can be kept without smell and the ether is completely cut off from the rest of the apparatus when the tap of the ether chamber is closed.

To anæsthetise by this method the indicator is turned so as

to be completely off the dial-plate, which is just above the face-piece. This opens the air way. The nitrous oxide tube is then fixed to the ether chamber, and the Cattlin's bag slowly filled with gas to two-thirds of its capacity. The bag should contain at least two gallons of gas. The face-piece is then applied and carefully fitted, the excess of air in the air cushion being liberated. When the patient is accustomed to the face-piece, that is in three or four respirations, the indicator is turned during an inspiration on to the dial-plate opposite the letter "G," which stands for "gas." The patient now is breathing nitrous oxide, and the administrator from time to time admits more gas into the bag. When the breathing, which at first is usually hurried and irregular, owing to the patient's nervousness, has settled into a quiet regular rhythm, the tap of the ether chamber is turned. Now the indicator is slowly moved over the dial from the letter G (gas) towards E (ether). If no check in the respiratory rhythm takes place, the ether vapour is made stronger and stronger, until, on the indicator reaching E, pure ether vapour is inhaled. If, however, the breath is held or cough occurs, the indicator must be put back for a respiration or so until toleration of the ether is attained. The supply of gas should be kept up to this point, but as soon as the indicator is at E the nitrous oxide is cut off by turning the foot-piece firmly to the right, and the india-rubber tube is detached. As soon as the patient breathes the ether freely and conjunctival reflex has grown sluggish, the face-piece is lifted, and the gas expelled from the bag. This may, in exceptional cases, be required sooner, the indication being marked cyanosis and respiratory embarrassment or sudden pallor.

Slight cyanosis and breath-holding are not necessarily signs for admitting air. If the face-piece is lifted too soon the patient will rapidly "come out" of the nitrous oxide narcosis, and his blood not being sufficiently saturated with ether, he will commence to struggle. On the other hand, if the ventilation of the lungs by admission of air is delayed too long, respiration will be seriously impeded and the heart become embarrassed. One if not more deaths have occurred through this accident, although the watchful administrator can hardly

overlook the obvious signs of danger, such as failure of respiration associated with deep cyanosis.

Care must be taken that the face-piece fits accurately, as if air leaks in around the air pad the patient will breathe very softly and draw the air in, but get little or no ether. When once muscular relaxation has occurred and the breathing is regular, the rules given above will guide the anæsthetist, air will have to be admitted from time to time, and all cyanosis carefully avoided. The gas tap should be kept open in order that air may be drawn in by the patient's inspiration. When, owing to respiratory spasm, or persistent cyanosis, oxygen seems indicated, it can be admitted through this tap.

ETHYL CHLORIDE FOLLOWED BY ETHER.

The portability of the rapidly evaporating anæsthetics like ethyl chloride and its mixtures renders them useful when nitrous oxide is unobtainable.

Many ways have been suggested by which the ethyl chloride may be given in sequence with ether, and reference must be made to a later chapter dealing with the anæsthetic more in detail for particulars and technique of the methods suggested.

The only essential for the closed method is that complete exclusion of air is effected while the ethyl chloride is being administered. When ethyl chloride is given by an open method, the plan to be adopted is somewhat modified, and is described in the section dealing with that anæsthetic (p. 305).

When separate inhalers are employed, the ethyl chloride (3 to 5 c.c.) is sprayed upon the inside of the mask according to the age and physique of the patient, and this is at once applied, all air being excluded. In 20 to 30 seconds stertor will be heard. The mask is then rapidly changed for a Clover's ether inhaler, already filled and arranged so that the patient at once breathes a full strength ether vapour.

But two inhalers are not necessary. The appropriate dose of ethyl chloride can be sprayed into the bag of the Clover's inhaler and as soon as unconsciousness is obtained the ether is turned on.

CHLOROFORM OR ITS MIXTURES FOLLOWED
BY ETHER.

The A.C.E., or better C.A., or even the C.E., is occasionally employed, an open mask such as Skinner's or Schimmelbusch's being used and the mixture dropped upon it until struggling commences or unconsciousness is established, when ether is given by the open method or by an inhaler. If chloroform is used, the same procedure is adopted.

The employment of these sequences is open to the obvious objection that chloroform or one of its mixtures is being employed at the period of its greatest danger, *i.e.* during the induction. If there is any real reason for using chloroform before ether it is best done by introducing the anæsthetic by means of the Vernon Harcourt chloroform regulator. But as some nervous persons are terrified by any apparatus this may be preceded for a minute or two by an open mask and a drop method. When morphine and scopolamine and atropine have been introduced an hour before the inhalation it is wise to deepen the narcosis by using a mask and drop method before passing to "open" ether, should that method have been selected for the anæsthetic.

The employment of **oxygen** with ether, which I have adopted for many years, is of great value. In cases in which the induction presents unusual difficulties from dyspnœa, spasm, cough, holding of the breath, struggling associated with cyanosis; in alcoholics; and in persons of feeble vitality, the repeated filling the bag connected with the ether inhaler with oxygen removes all difficulty, and rapidly induces quiet anæsthesia. The narcosis so obtained is more profound than can be ensured when using ether by itself, as the hyper-oxidation of the tissues enables more ether to enter the circulation than could otherwise occur without danger to the nervous centres, hampered as they probably would be by deoxydised blood. The plan I pursue is to admit the oxygen through a second tube fitted to the Clover's gas and ether inhaler *pari passu* with the ether, and either give the oxygen intermittently or continuously as occasion seems to demand. The oxygen certainly acts as a powerful stimulant, and is very valuable in prolonged and exhausting operations as a corrective to shock.

3. NASAL METHOD—PHARYNGEAL ANÆSTHESIA.

Mr. H. M. Page* has adopted Dr. G. Crile's method of introducing ether vapour through the nasal passages in cases in which it is desirable to leave the mouth free for operation. The principle is to shut off the mouth cavity from the upper air passages, so as to prevent aspiration of blood or septic material, and to remove the anæsthetist and his paraphernalia from the site of operation. A preliminary tracheotomy and plugging of the larynx involves certain risks, and if a nasal venue for the anæsthetic is possible, it is a gain to the patient.

Method.—The mouth, nares, and naso-pharyngeal space should be carefully cleansed by spraying, gargling, or other means, and the patency of the nares be investigated.

If the lumen of the passages is lessened by tumefaction and congestion of the turbinates, a pledget of cocaine and suprarenin may be inserted, or the mucous membrane wiped with a mop holding cocaine, until ischæmia is established.

Anæsthesia is now obtained by ordinary means, and it is usually wise to prepare for it by a hypodermic injection of morphine, scopolamine, and atropine given one hour previously. Mr. Page suggests morphine gr. $\frac{1}{4}$, atropine gr. $\frac{1}{8}$.

As soon as the patient is fully anæsthetised, and has taken sufficient ether to ensure his remaining quiet for some minutes, the tubes (see fig. 41) are introduced into the nares until the lower ends are opposite the epiglottis, and then the mouth is well opened with a gag of wider stretch than is commonly obtained; the pharynx is carefully and systematically packed, the tongue being drawn forward out of the mouth. A sterilised gauze roll $1\frac{1}{2}$ to 2 inches wide answers well, and this must be introduced so that the sides as well as the centre of the pharynx are completely shut off from the mouth. In packing care must be taken to avoid compressing the tubes, especially since it is essential that the packing should close in the outer sides of the tubes. The apparatus, which is figured, consists of two nasal rubber tubes, of sufficient size to block the nares, and these are connected by a Y-shaped glass piece with a wider bored tube. This, again, if open ether by a drop

* *Lancet*, 1909, vol. ii. p. 364; *Brit. Med. Jour.*, Sept. 14, 1912.

method is to be used, is fitted to a glass funnel covered with gauze. Mr. Page finds that in many cases the funnel is best replaced by a connexion between the tube and a Vernon Harcourt chloroform inhaler, thus giving chloroform instead of ether. Oxygen can be supplied with the anæsthetic. For operations about the mouth a light narcosis is required, so that a "faint corneal" reflex (Page) should be retained throughout.

Kühn intubates with his special apparatus. The tube is continued some way out of the mouth to a funnel covered with domett. On this ether is dropped.

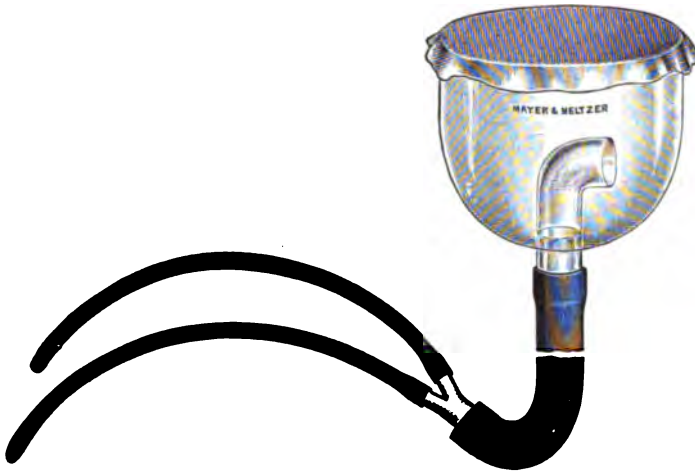


FIG. 41.—Crile's tubes for nasal etherisation.

Mr. Souchon* has devised an ingenious instrument for effecting pharyngeal anæsthesia. It is worked by a hand-pressure ball. The same procedure is carried out in a different manner by Dr. H. R. Thoms.† He employs a somewhat complicated apparatus, which allows a plenum ether vapour atmosphere to enter the naso-pharynx by admitting oxygen under pressure to an ether chamber, which is kept warmed by an electric-heater, and passing thence by a soft catheter through the nares enters the post-nasal space.

* *Med. News*, Philadelph., Nov. 23, 1895, and "Surgery, Gynæcology, and Obstetrics," vol. xiii. p. 169.

† "Surgery, Gynæcology, and Obstetrics," 1911, vol. xiii. p. 695.

B. INTRA-VENOUS ETHER INFUSION.

To Burkhardt* we owe the method of introducing ether directly into the blood stream. The success which followed experiments upon the lower animals led him and others to employ it for man, but the first attempts, although successful, revealed the necessity for a special apparatus and technique. Experience has proved the superiority of employing a *continuous* instead of an intermittent flow into the vessels.

H. Küttner, one of the first to use the method, has cautioned against the danger of air embolus and thrombosis, and these dangers are greatly diminished by the continuous flow system. Goyane's† advocacy of the plan of introducing the ether and saline into an artery has not been responded to, indeed the advantages claimed for the method hardly counterbalance its obvious dangers. Thus much had been demonstrated alike by Flourens and Claude Bernard. Prof. August Bier, Dr. J. L. Ransohoff, and others sought to avoid these dangers by localised intra-vascular injections of various drugs cut off from the general circulation by tightly fitting bands, but this procedure is of limited application. As we know intra-venous infusion at the present time it is confined to the use of ether, hedonal and isopral (see below) with the less frequent use of paraldehyde,‡ since chloroform employed in this way is extremely dangerous. Dr. F. S. Rood§ has elaborated an excellent apparatus (fig. 42). This consists of a glass reservoir (A) capable of holding about three pints of saline containing ether, supported on a stand eight feet above the floor level. This reservoir is controlled by a ground accurately fitting stopcock on the drawn out end of the reservoir and is connected by a rubber tube with the regulating chamber (B). This has three openings, one uniting it with the reservoir, one connecting it by a rubber tube with the warming chamber controlled by an accurately fitting glass stopcock, and one

* "Archiv. of Experiment. Pathol. and Pharmacol.," Bd. 61, p. 323.

† *Siglo Medico*, Oct. 9 and 16, 1909.

‡ *Lancet*, Nov. 2, 1912, p. 1220.

§ *Brit. Med. Jour.*, 1911, vol. ii. p. 974; 1912, p. 608; and *Proc. Roy. Soc. Med.*, 1912, vol. v., pt. I. p. 77.



FIG. 42.—Ether-infusion apparatus of Dr. F. S. Rood.

which admits air, is capable of airtight occlusion by means of a rubber or ground-glass stopper. Personally I prefer the former, *i.e.* the rubber stopper, as less liable to jam. When the reservoir tap is opened and the regulating-chamber tap is closed, the saline-ether solution enters the regulating chamber and as soon as it is half full the air

A 5 per cent. solution of ether in normal saline flows from a reservoir, which is fixed 8 ft. above the floor level, through the indicator, and then through a warming chamber into the cannula, and so into the vein. The indicator consists of a cylindrical bulb with a capacity of 8 oz. When the apparatus is working, the lower half is full of the solution, while the upper half contains air. The solution flows from the reservoir into the bulb through a pipette, and drips on to the surface of the fluid below. The system being a closed one, the pressure within it is transmitted through the indicator by means of the air contained therein; hence it follows that the rate at which the solution drips from the pipette furnishes a satisfactory index of the rate at which it is entering the vein. The flow is entirely controlled by one tap placed immediately below the indicator.

A. Reservoir with stopcock, holding about three pints of the ether solution.

B. Indicator with stopcock and air inlet.

C. Warming chamber in copper hot water receptacle.

D. Arm rest.

The apparatus can be supplied with two reservoirs, one to contain the ether solution, and the other normal saline with V-shape connexion in order that saline may be turned on immediately if required.

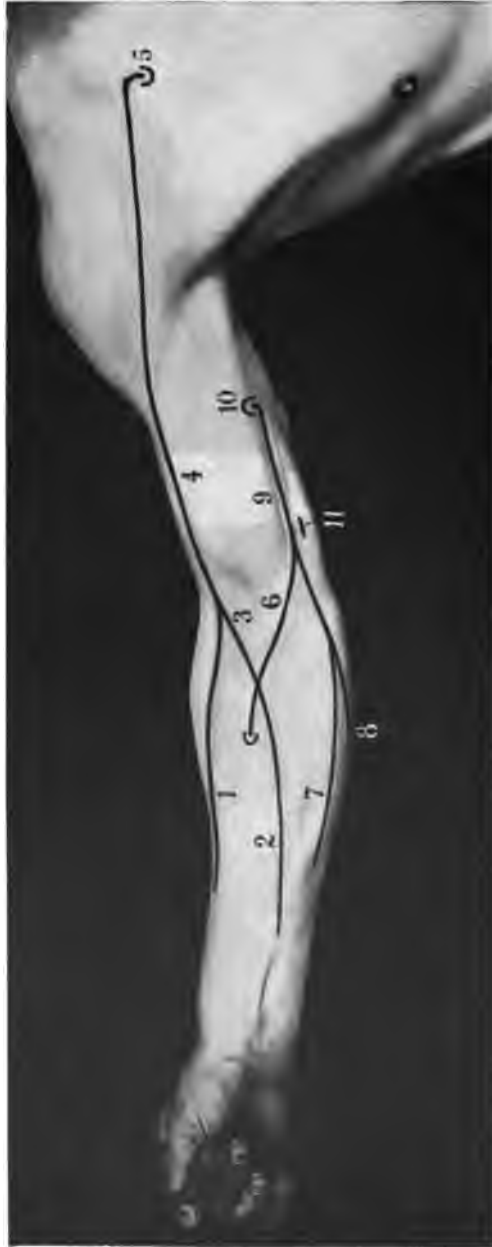
inlet is closed by inserting the stopper, and as a result the air in the chamber becomes compressed by the fluid in the chamber, so that the fluid as it escapes from the regulating chamber into the warming chamber is under pressure and so passes in a continuous flow into the tube connected with the cannula. The warming chamber is immersed in warm water, the temperature of which is regulated according to the state of the weather, the object being to warm the saline to a temperature below that at which the ether escapes in bubbles. This chamber, which is constructed of glass, has its egress tube nearly half-way below its summit in order that any air or volatilised ether may rise to the top of the chamber while only fluid traverses the egress tube. This last is connected by a rubber tube roughly the diameter of the distended vein with a glass or metal cannula which is to be introduced into the vein.

Technique.—The solution is prepared by shaking ether in sterilised normal saline until it is thoroughly dissolved. Saline* takes up 10·8 per cent. by volume of ether, but a 5 per cent. ether solution is the best for ordinary use, although it is permissible to use a 7·5 per cent. after induction by the lower strength. Some of the earlier workers employed a 10 per cent., and I have done so myself with the result that hæmolysis has occurred and the urine contained blood-colouring matter. This is probably due to destruction of the erythrocytes in the vein in the immediate neighbourhood of the cannula, as when the ether solution is diffused through the blood stream it is rapidly diluted to a safe strength, especially so if the operation is in progress and hæmorrhage is occurring.

The whole of the apparatus is sterilised by boiling, and is then put together. The reservoir is nearly filled with the solution and a gauze cap laid over its inlet to keep off dust, the reservoir tap is opened, and the regulating chamber filled half with air and half with solution, as already described.

* Mr. R. R. Bennett (*Pharm. Jour. and Pharmacist*, Aug. 3, 1912) has conducted an investigation into the solubility of ether in normal saline and his findings are as follows: Normal saline is made by dissolving 0·91 grms. of pure sodium chloride in 99·09 grms. of distilled water. The average solubility of grammes of purified ether prepared from methylated spirit dissolved in 100 grms. of normal saline at temperatures between 0° C. and 30° C. are—0° C., 13·46; 5°, 11·55; 10°, 9·87; 15°, 8·50; 20°, 7·38; 25°, 6·46; 30°, 5·83.

PLATE IV.



3. The median-cephalic vein.
4. The cephalic vein.
5. The point at which the cephalic vein pierces the costo-coracoid membrane.
6. The median-basilic vein.
7. The position of the cephalic and median basilic veins is shown. Into the larger of these the cannula is inserted.
8. The basilic vein.
9. The point at which the basilic vein pierces the deep fascia.
10. The point at which the basilic vein pierces the deep fascia.
11. The point at which the basilic vein pierces the deep fascia.

The regulating-chamber tap is now opened and a continuous flow allowed through the warming chamber until this last has been freed of air. Some ether will volatilise and bubble up, but this is of no importance as it is reabsorbed and cannot enter the vein. When the whole apparatus is free of air and full of saline-ether solution the regulating chamber tap is closed, and as soon as the air in it is compressed to its limit the flow from the reservoir will cease. If it does not this will be due to some leakage out of air which must be sought for and prevented. The warming chamber (C) is now placed in the hot-water receptacle and the cannula and tube placed in sterilised water.

Preparation of the patient.—It is advisable to prepare the patient in the usual way and to give a hypodermic injection of morphine gr. $\frac{1}{8}$, scopolamine gr. $\frac{1}{100}$, and atropine gr. $\frac{1}{100}$, one hour before the infusion is to be made. The doses of these may vary with the individual patients. As a rule the arm is the best limb to select for the infusion, as the leg veins are less easily manipulated and are farthest from the head, a disadvantage since it is necessary for the anaesthetist to be able to prevent mechanical interference with respiration due to falling back of the tongue and dropping the jaw and so on. The arm selected should be that farthest away from the place where the operator will stand during the operation. The next thing is to carefully cleanse the bend of the elbow and paint it with a preparation of iodine. The larger of the two veins—the median basilic or the cephalic—should be selected, and, unless it is large and stands out well, being uncovered by loose fat, its course had better be marked with nitrate of silver (see Plate IV.). The area about the site at which the vein will be opened is now infiltrated with β -eucaine solution, care being taken to introduce the solution below the vein as well as in its periphery. After a few minutes the oedema disappears and the line of the vein is fairly evident. If it is not visible the patient should grasp a stick in his hand and a fillet should be tied round the arm some way above the elbow. The arm is now placed on the arm-rest (D) covered by a sterilised towel and secured in position with a bandage fixed below and above the elbow. A slanting incision across the line of the vein is

then made and the vein defined and cleaned. Two ligatures are passed round it ; of these the peripheral one is tied. The cannula and rubber tubing are now fitted to the egress tube of the warming chamber (C) and some solution allowed to flow through the cannula to remove all air in order that so soon as an incision is made in the vein the cannula can be introduced and tied in. The danger of its slipping out is in this way prevented. Some surgeons have adopted the use of a metal cannula such as is used for salvarsan injection and plunge this into the vein without any preliminary dissection. My experience is not in favour of this procedure as it is often difficult to avoid going right through the vein and infiltrating the tissues ; besides this the trauma which occurs with this method seems more severe than that due to a deliberate dissection. The few minutes saved are really of no moment in the case of a drugged patient whose arm is analgesic and when neither sedative drug nor analgesic is employed the pain inflicted by the stab of a sharp cannula seems hardly justifiable unless a very definite counterbalancing benefit accrues from the procedure. The rate of flow is controlled by opening or partly closing the regulating chamber, and the anæsthetist by watching the flow or dropping from the reservoir into the regulating chamber can gauge quite accurately the amount of fluid passing into the vein.

Administration.—The above preliminaries having been carried out, the administrator steadies the arm and removes the constricting fillet. He should notice whether the flow continues, and, if it does not, he should ease the cannula and correct any flexion at the elbow or kink in the tubes. Full flow should be permitted at first, and in a minute or so the patient's breath will smell of ether. Muscular subjects may struggle and bend the arm, thus causing back pressure and forcing blood into the warming chamber, but usually by keeping the arm firmly on the rest this can be prevented or corrected, and the flow goes on, when anæsthesia rapidly occurs. If the cannula is forced out, the vein must be at once compressed above the opening into it and the cannula re-entered and secured more efficiently. When anæsthesia is present the supply of ether is lessened by partly closing the

tap from the regulating chamber, but cessation of flow must never be allowed, lest clotting in the cannula occur, an event not devoid of danger. As the operation goes on, constant modifications in the rate of flow will be called for, but experience will enable the administrator to regulate the degree of narcosis with great accuracy. A slight excess of ether often causes cyanosis, especially if the jaw is allowed to drop, and cessation of respiration is not uncommon. This symptom, which may appear alarming, need not be so, for a lessening of the ether supply and a gentle pressure on the ribs will at once restart breathing. It need hardly be pointed out that the utmost vigilance is necessary, as, although the danger is trivial if at once noticed and dealt with, it may become most serious if neglected. Muscular, vigorous persons upon whom a difficult dissecting operation has to be performed, *e.g.* one on the abdomen, may need a higher percentage of ether, but this is very seldom the case, and if the necessity arises it is a very simple matter for an assistant to add more ether-saline solution to the reservoir, increasing the strength of the solution. If the solution has been made stronger, it should be again lessened in strength as soon as possible. It is essential also, so far as the exigencies of the case permit, to limit the amount of fluid introduced. Koenig and others have asserted that fatal accidents have resulted from excessive quantities of saline entering the circulation. Upon the other hand, a moderate quantity of saline unquestionably exercises a powerful influence in the direction of lessening collapse. Probably the slowness of introduction is a safeguard when the flow is continuous. The narcosis is usually induced without struggling or discomfort, is light in character, and the patient resumes consciousness within a few moments of the cutting off of the ether solution. As soon as the operation is seen to be nearly over, the ether solution should be materially lessened, and when it is completed the cannula must be withdrawn and the vein secured by clamp forceps. The vein is now completely severed, and the proximal as well as the distal ends carefully secured with ligatures so placed that the portion of the vein which has been subjected to injury, *e.g.* by the insertion of the cannula, cleaning away of peri-vascular tissues, and so on, can be cut away. The wound, which should have been kept

moist and sterile during the operation by a pledget of sterilised gauze wetted with saline, is irrigated with saline and the requisite stitches inserted and dressing applied. If cleanliness has been properly seen to and the vein has not been damaged during efforts to insert the cannula there is little fear of local trouble.

After effects.—Those usually associated with ether inhalation may occur, but their incidence is probably less in intra-vascular infusion. Vomiting and pulmonary complications are rare, but both may arise. Albuminuria, with hæmoglobinuria, due to over-concentration of the solution, and subcutaneous hæmorrhages have been seen. A severe attack of jaundice followed in one of my cases, but it was impossible to say whether the ether had any causal relation with the symptom. The patient was otherwise none the worse, and the jaundice soon disappeared. Thrombosis, air embolism, phlebitis, and plugging of vessels by thrombosis have all been reported, and although most of these dangers can be avoided by an accurate technique and experience of the method, they have to be reckoned with, especially when unsuitable patients are so treated, or the administrator has little experience of the method. The knowledge of about five hundred cases induces Dr. Rood to regard the method as comparing very favourably in the point of view of safety with others, and my own observation certainly bears out this contention.

Suitable cases.—The type of patient which suggests saline infusion to stave off shock is peculiarly appropriate for intra-venous etherisation. Abdominal sections, especially in acute cases, extensive operations about the upper air passages, are all suitable. The young and the aged lend themselves equally to it if due care is taken to limit the amount infused to the capacity of the patient.

When the field of operation involves the mouth, pharynx, or larynx the anæsthetist must keep control of the head, to prevent blood being aspirated into the air passages; respiration must be watched to prevent its being hampered by displacement of the tongue.

INTRA-VENOUS INFUSION OF HEDONAL.

Federoff and Jeremitsch, having satisfied themselves by experiment upon animals, adopted the use of hedonal, methyl-propyl-carbonyl-methane ($\text{NH}_2\text{CO.O.C.H.CH}_2\text{C}_2\text{H}_5$), as an anaesthetic for man. They employed an interrupted infusion method, a 0.75 per cent. in normal saline being injected under air pressure. The needle was inserted into a superficial vein, and sufficient of the hedonal solution injected to produce anaesthesia; it was then withdrawn to be re-inserted if a prolongation of the anaesthesia was necessary. The results obtained were on the whole satisfactory, but less so when leg veins were injected. Respiratory trouble occurred.

Mr. C. M. Page,* whose apparatus for intra-venous infusion of hedonal has been modified by Dr. Z. Mennell, has used this means of attaining anaesthesia in a number of cases at St. Thomas' Hospital, and regards it as valuable, but cautions against its employment in unsuitable cases.

Hedonal is a white crystalline solid, stable at ordinary temperatures. It dissolves in water at 100°F. to 1 per cent., and is unchanged by boiling. It produces some fall in blood pressure; in toxic doses the vaso-motor centre is paralysed. Cyanosis is apt to appear, and respiration is slowed.

The solution is made by dissolving hedonal in sterile saline at 75°F., 0.75% strength being employed. This is filtered, boiled for five minutes, and stored in sterile flasks.† It is heated to 105° or 110°F., as higher temperatures lead to local thrombosis. Mr. Page adopts a continuous infusion, and finds 500 c.c. is an average amount per patient. The induction period is 2 to 13 minutes, and the narcotic effect of the hedonal persists for a long time after infusion has ceased. Muscular relaxation is satisfactory. There is a fall of blood pressure and some cyanosis; this latter is commonly due to the tendency of the tongue to fall back unless closely watched, or fixed so that it cannot occlude the glottis.

* *Proc. Roy. Soc. Med.*, sect. "Anæsthetics," 1912, vol. v. pt. I. p. 84. Mr. Page gives a useful resumé of the subject, and the author is greatly indebted to him for his kindness in supplying information and allowing his apparatus to be figured.

† Hedonal crystallises out of its solution on cooling. It may be kept for some weeks redissolved preparatory to injection.

Apparatus.—Consists of a tank supplied with a thermometer and gauge, and a tapped outlet tube. From the tube runs a yard of pressure tubing, in the course of which is a dropper; ultimately the tubing ends in a fine infusion cannula.

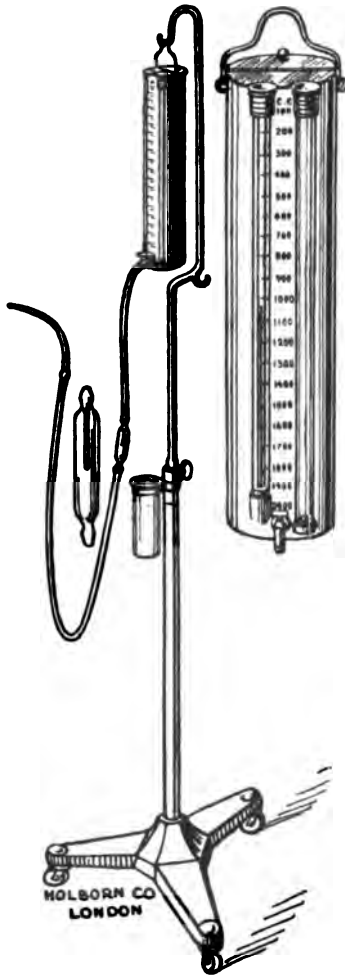


FIG. 43.—Mr. Page's hedonal infusion apparatus.

The introduction of the cannula into the vein is conducted in the manner already described in the case of ether infusion. Dr. Mennell employs the internal saphenous vein where it passes over the malleolus.

The phenomena of induction are: drowsiness with yawning appears in about one minute, there is usually no struggling; complete muscular relaxation and chin drop occur, the latter calling for care lest the tongue fall back, so impeding respiration.

Amount required.—40 c.c. were required to anæsthetise a child of 10 months, 1,000 c.c. for a heavily built man of 25 years. When anæsthesia has been induced, the amount of solution is cut down to a slow dropping, but the rate varies in each case, and has to be gauged by experience. Dr. Mennell gives 30 to 60 drops per minute as an average. Less than 10 per minute allows clotting.

Post-operative effects.—Mr. Page points out as possible dangers the onset of cyanosis, and Federoff records some instances of temporary cessation of respiration. There is danger of vomitus or blood entering the air-ways during the

post-operation profound sleep, since this coma may last for 6 to 12 hours. In a few cases emotional manifestations occurred; in some headache. In three cases there was some local thrombosis. No hæmolysis was observed.

Contra-indications.—The method seems unsuited in cases in which pulmonary engorgement or gross cardiac lesions exists, in operations on the air passages, in cases with high blood pressure.

The preliminary use of morphine or scopolamine appears a doubtful advantage, since, although it lessens the necessity for giving so much hedonal, it increases the danger of the post-operation sleep period. Mr. Page suggests giving 3 grm. of hedonal about two hours before infusion, restricting its use, however, to the strong and physically fit.

Some fatalities have been reported occurring after the use of hedonal infusion, but although possibly discouraging they do not lessen the value of the method or contra-indicate its use in appropriate cases. Dr. Veale* has investigated the fatal cases which occurred at Leeds, and considers pulmonary complications, as well as venous and cerebral thrombosis, are all liable to occur after hedonal infusion. Sir Berkeley Moynihan,† who has designed an apparatus for hedonal infusion, appears to consider the use of this method to be satisfactory in spite of its alleged shortcomings.

It seems probable, therefore, considering the experience so far obtained, that while hedonal as an anæsthetic is certainly valuable, yet the powerful and persistent properties of hedonal as a drug render its introduction into the circulation a procedure demanding special care and knowledge, as well as a wise discrimination in selecting cases. Special after-watching is also necessary.

A discussion on the use of hedonal‡ held before the Medical Society of London provoked somewhat divided views. Dr. F. Mennell's experience with head cases was favourable to hedonal. He enjoins caution in its use, as its close relationship with veronal proves its possible dangers in inexperienced hands. Dr. Mennell has had a wide experience

* *Brit. Med. Jour.*, Aug. 17, 1912, p. 347.

† *Lancet*, June 15, 1912, p. 1631. See also p. 1258 for Mr. Page's paper.

‡ *Trans. Med. Soc.*, Oct. 28, 1912.

with hedonal, and although he regards it as valuable in intra-cranial operations he considers that it is of the utmost importance to limit the dose. Indeed, he has lessened this considerably from that at one time recommended. This warning is enforced by Dr. G. A. H. Barton,* who has met with serious complications during the use of this anæsthetic. Mr. Dobson giving his experience at Leeds reported a number of deaths and serious mistakes, but of these not a few appear to have been not by any means due to hedonal alone. Dr. L. E. Barrington-Ward has used hedonal infusion for children and upon the whole he favours it, although he points out very fairly that as many fatalities have followed its use, unless the administrator is an adept and the patient a suitable one, hedonal is undoubtedly a dangerous drug. The difficulty of knowing when the patient is unconscious is increased in the case of children. Most observers are inclined to recommend the use of a much smaller quantity of hedonal than obtained in the first and to maintain in all cases the "skin reflex," by which is meant that the patient moves when the skin is incised, although he is quiet afterwards. The ocular phenomena are valueless with this anæsthetic, as loss of conjunctival reflex would indicate a most dangerous depth of narcosis. Professor Burkhardt regards hedonal as dangerous and prefers isopral and ether.

C. INTRA-TRACHEAL INSUFFLATION OF ETHER.

Tuffier (1897), Kuhn, and Lotsch employed laryngeal intubation to produce plus pressure in the lungs as well as anæsthesia, but the inception of the method, as applied to promoting anæsthesia for surgical operations, was rendered possible through the experimental work undertaken by Drs. S. J. Meltzer and John Auer of New York,† while its practical application we owe in no small part to Dr. C. A. Elsberg, of New York. Meltzer and Auer demonstrated that if a tube two-thirds of the diameter of the trachea is introduced into

* *Brit. Med. Jour.*, Sept. 14, 1912.

† *Jour. of Experimental Med.*, 1909, vol. ii. p. 622, "Continuous Respiration without Respiratory Movements," by S. J. Meltzer and John Auer. From the Rockefeller Institute for Medical Research.

it nearly to its bifurcation, respiration with full aëration persists, but with lessened respiratory movements. They urge that as a result of their method (1) "The lungs are kept in [a] continuous inspiratory state of distension, which facilitates the exchange of the gases. (2) The fresh air enters the lowest part of the trachea. (3) The [expired] air escapes by another path (although also through the trachea) than by the one it enters."

Before dealing with the purely practical aspects of the intra-tracheal insufflation method it may be well to sum up briefly Dr. Meltzer's conclusions. Not only does his high reputation lend weight to these, but as he has published his experiments it only remains for us to accept as proven the basis upon which the method is founded. It would be difficult to find any finer piece of experimental work than Dr. Meltzer's researches bearing upon the subject under treatment. The principle of the effectiveness of the method is based upon its cutting out the greatest part of the dead space in the respiratory mechanism since the ether vapour and air are carried by the intra-tracheal tube directly to the bronchi at the bifurcation of the trachea. The outgoing current of air escapes with so much force, since a plus pressure has been established in the lungs, as to absolutely prevent mouth aspiration, thus protecting the patient from the entrance of infective material from the mouth or pharynx. Charcoal dust in the mouth never enters the air passages while intra-tracheal insufflation takes place.

Dr. Meltzer has shown that the common assumption that the tracheal mucous membrane is delicate and sensitive is not consonant with fact. The intra-tracheal tube does not cause hurt or spasm. During this method the thorax may be opened and operations performed on the lungs and pleuræ without inconvenience or interference with air exchange. Since the ether passes directly into the lungs very little is needed to establish and maintain anæsthesia. If an overdose is given the respiration stops and the blood pressure falls, but falls very slowly, but when the ether is cut off and replaced by air, recovery rapidly occurs.

Since the regions innervated by the trigeminal and superior laryngeal nerves are not within the zone of the

ether's action, the reflexes, often troublesome during mouth and nasal inhalation of ether, are absent in the tracheal method.

Dr. Meltzer's experiments prove further that the size of the intra-tracheal tube is important: if too large, elimination is interfered with; if too small, the narcosis is apt to be too light. To avoid too high a pulmonary plus pressure an automatic safety valve and a manometer are essential. It is also necessary to protect the patient from pressure or twisting of the trachea, since such an occurrence is most dangerous. The ingoing current of air and vapour must be constant, although the pressure must be lessened frequently to assist circulation and avoid emphysema. If ether apnœa occurs the anæsthetic must be shut off while air or oxygen is continued. Finally, the method is the best one for use to carry out artificial respiration, the ether being omitted.

A large number of apparatus have been devised to fulfil the requirements of the method. Of these Dr. Elsberg's, which, if the most complicated, is probably the best type, is described below, although the simpler patterns which have been adopted in this country will receive brief mention. As the technique and the precautions necessary in each modification of Elsberg's method are practically the same, one detailed description will suffice.

DR. ELSBERG'S* APPARATUS AND TECHNIQUE.

The preparation of the patient is carried out along usual lines, and he is anæsthetised by the usual method, including the preliminary use of atropine and morphine.

Description of apparatus.—The blower D is operated by a $\frac{1}{2}$ h.p. electric motor, controlled by a switch (A). B is the rheostat. The air passes through the tube E and the oil filter F and the tube G into the bottle H. The bottle H contains hot water, which warms, moistens, and filters the air. On leaving the bottle H the air passes by a rubber tube (I) to the tracheal catheter. To I is connected the ether container J. This consists of a glass jar, held air-tight

* *Annals of Surgery*, vol. liii. p. 161. The more recent form of this apparatus has been greatly simplified.

against its cover by a spring clamp. * The cover contains two tubes, X and X¹, which are connected with the main air-tube I. The hand-wheel K controls the air passing through I by an indicator. Thus pure air or pure ether vapour, or any degree between, can be obtained and is indicated. If pure air is entering, the ether container can be removed and re-

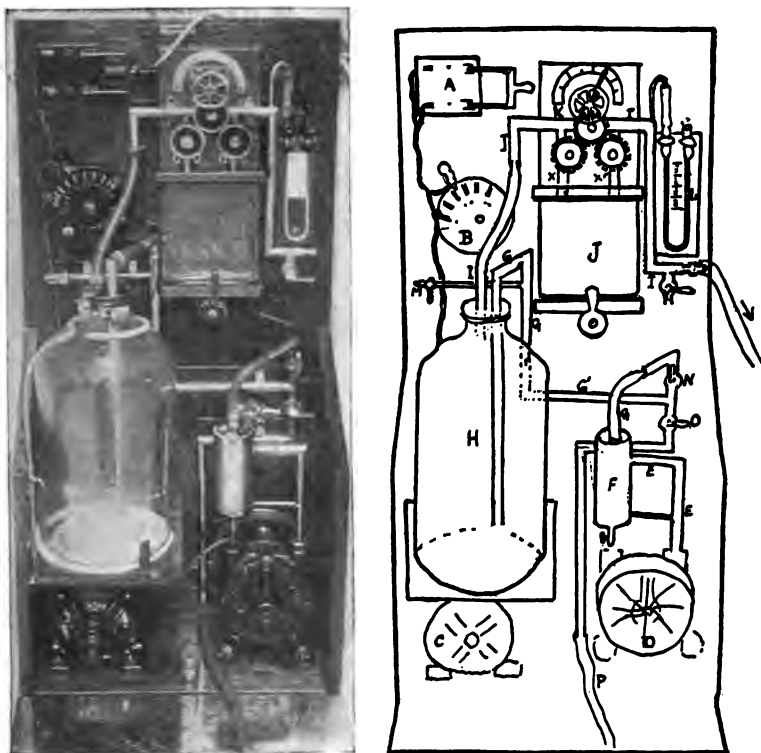


FIG. 44.—Dr. Elsberg's apparatus.

plenished, as X and X¹ are closed. The manometer L is connected with I, and records the pressure of air passing through I. The tube M, controlled by a stopcock, enters G, and serves to admit oxygen from a tank to which it is connected. The tube P leads to a foot bellows, for use if the motor breaks down. When the stopcock N is closed and O is open, the air enters from the foot bellows, traversing the tube G¹. When the apparatus is in use the water bottle has one-

third of water in it, the two stopcocks on the manometer are opened, the stopcock N is opened, O is closed, and the rheostat is turned on full. M is left wide open. As soon as the apparatus is connected with the intra-tracheal catheter already *in situ* M is slowly turned until the pressure, as indicated by the manometer, is reduced to 20 mm. The strength of ether supplied should be made to vary with the patient's condition and the requirements of the operator. If it is desired to divert the air and ether current from the patient, this can be done by the stopcock I below the manometer.

A fairly rigid silk woven catheter, with an opening at or near its end 30 cm. long, is selected. Two marks are made upon it, one 12 cm. and one 26 cm. from the tip. If this latter mark is opposite the incisor teeth, the end will be 5 cm. above the bifurcation of the trachea.* The size of the catheter selected will depend upon the diameter of the trachea; one, the diameter of which is about half the length of the glottis, easily judged by direct inspection, will be best. The average for the adult is No. 22 or No. 24 French. Dr. Elsberg finds that the length of the catheter between the teeth and the glottis is about equal to the length of the catheter below the glottis. The catheter is introduced by means of Jackson's direct laryngoscope, in the same way as when that instrument is used to introduce the bronchoscope. It is well to let the head be thoroughly extended and the mouth gagged open, the epiglottis being held forward by the back of the laryngoscope. The catheter is introduced through the instrument, and pushed on until the 26 cm. mark is opposite the incisor teeth. The hiss of the air through the catheter assures that it has entered the trachea, and is not curled back on itself. Its introduction may set up laryngeal spasm, but this soon passes off.

An arrangement of wire running below the nose, and hooking over the ears like a spectacle-frame, can be used to fix the catheter in position. After connecting the catheter up, the pressure should be kept at about 20 mm., and the ether index about 50, but some patients require more ether. A

* According to Brünig the average length of the male trachea and the distance from the glottis to the incisor teeth is 26 cm., while in females the length is 23 cm.

higher pressure is said by some authorities to be free from danger, although obviously a prolonged markedly plus pressure in the lungs is a condition making for undesirable developments. It is wise occasionally to permit the lungs to partly collapse, otherwise cyanosis and heart strain are apt to be caused. Cyanosis, however, may be due to other causes, viz. that the catheter has too large a diameter, or is not pushed far enough into the trachea, and when these errors are corrected the normal colour of the patient returns. On the other hand, if the catheter is introduced too far it sets up spasm and coughing, at once relieved by a slight withdrawal. During the insufflation the expired air, mucus and so on, pass up and out beside and around the catheter, so that no aspiration of blood or other fluid can ever take place, owing to the strong up-draught. After effects are, as a rule, absent. Although, as stated above, apnœa follows the commencement of insufflation, it is not always the case, especially when the pressure is kept low, for then slight, almost imperceptible, respiratory movements occur. This apnœa, when seen for the first time, is apt to cause embarrassment and anxiety, but no danger need be feared provided the patient's colour is good and air is whistling out of the trachea, and the pressure-gauge indicates that no undue pressure exists. An additional safeguard is supplied in most of the apparatus in the form of a safety valve, which permits a "blow out" to occur whenever the pressure reaches above the point which the administrator regards as the limit of safety. Some, indeed most, authorities insist upon the importance of warming the ether vapour and filtering the air before admitting them to the apparatus.*

There are now many forms of apparatus for intra-tracheal insufflation. Mr. Kelly, of Liverpool, whose machine is figured below, has simplified Dr. Elsberg's, while Dr. Ehrenfried of Boston, Dr. Shipway, and Mr. Boyle of London, have introduced very simple apparatus.

Mr. R. E. Kelly's apparatus † consists of a $\frac{1}{8}$ h.p. electric

* Dr. Meltzer (*Proc. International Med. Congress*, 1913, subsection "Anæsthetics") gives a valuable exposé of the method, and figures a simple but efficient form of the intra-tracheal insufflation which he has found to work as well as the more elaborate apparatus of Elsberg and others.

† *Brit. Med. Jour.*, 1912, vol. ii. pp. 112 and 617.

motor actuating a rotary blower—hypreso, size OO—which introduces the blast of air into a cleansing chamber containing

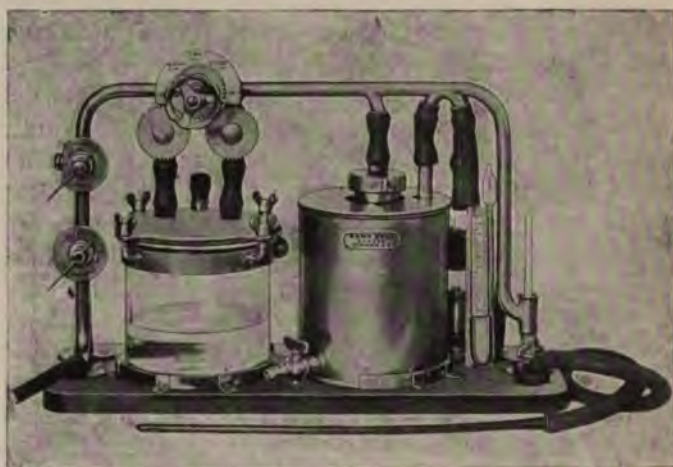


FIG. 45.—Mr. R. E. Kelly's intra-tracheal insufflator.



FIG. 46.—Motor actuating Mr. Kelly's insufflator.

water, thence it travels to an ether chamber constructed upon the "surface carburetter" principle. The pointer is the control and by turning it to full all the air passes over the

ether, or turning it to O no ether mixes with the air. Intermediate strengths of ether are obtained by intermediate positions of the pointer. The air and ether vapour then pass through a coil of lead tubing which is kept at the required temperature by an electric hot plate controlled by a switch. A manometer and thermometer are placed in the circuit between the heater and the tube which connects with the intubating catheter.

A much simpler apparatus has been devised by Dr. Ehrenfried,* and consists of a Wolff's bottle with three necks, sitting within a copper water jacket, and a foot bellows. By means of stopcocks on the outside of the jacket the stream of air from the bellows can be carried through the hot water over the surface of the ether (contained in the Wolff's bottle) or through the ether when a particularly strong vapour is desired. Air and ether vapour may be mixed in any proportion. Connected with the delivery end of the apparatus is a safety valve and pressure regulator consisting of a bottle of mercury into which a tube is plunged. The depth of the tube in the mercury, which is adjustable, represents the maximum of pressure which is allowed within the apparatus; if, for any reason, such as a spasm of the glottis, the pressure should rise, the valve "blows off automatically and danger from interstitial emphysema is avoided." The temperature of the ether and air should be 10° above room temperature. The catheter is passed into position by an introducer, a laryngeal forceps with sleeves attached for grasping the tube near its extremity similar to the Doyen introducer. The left forefinger is placed on the epiglottis and the instrument introduced without the use of head mirror or electric illumination.

One of the best apparatus in use in this country is that devised by Dr. Shipway. The illustration (fig. 47) will enable the reader to understand the working of the instrument. It is a modification of Kelly's apparatus, being more compact, and the length of tubing between the ether supply and the patient being curtailed enables the anæsthetist to deliver his ether air mixture at about body temperature. Dr. Shipway cocaineises the epiglottis and neighbouring structures, using a 5 per cent. solution, and passes the catheter by direct vision, using Hill's

* *Boston Med. and Surg. Jour.*, vol. clxiv. No. 15, April 13, 1911, pp. 532-35.

laryngeal endoscope distally illuminated with a detachable sterilised shield to protect the lamp. A small pocket battery can be attached to work the lamp. Dr. Shipway uses an electric motor.

Dr. Meltzer found that it is extremely difficult to kill dogs by insufflation, and he only succeeded in doing so after ten



FIG. 47.—Dr. Shipway's intra-tracheal etheriser.

The motor and blower are not shown in the figure.

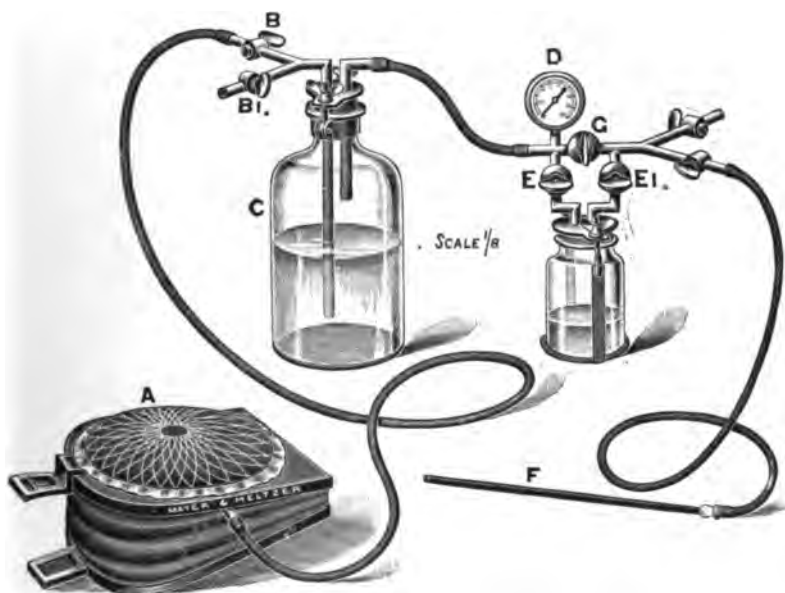
- | | |
|---|--|
| 1. Pressure regulator. | 6. Mercurial manometer. |
| 2. Oxygen inlet. | 7 & 7a. Hot-water tank with emptying tap. |
| 3. Mercury safety valve. | 8. Chamber for moistening air current. |
| 4. Automatic arrangement for passing any desired amount of air over ether. | 9. Thermometer. |
| 5. Ether bottle with arrangement for passing any desired amount of air through ether if required. | 10. Tap to lower pressure when required and connection for tubing. |

Size—15, 6½ × 12½ in. high.

hours of continuous etherisation. However, several deaths of patients have been reported from the U.S.A., although the fatalities it is alleged were due to errors in technique rather than to any danger inherent in the method. An interesting demonstration of its safety as regards vomiting is recorded both by Dr. Meltzer and Mr. Kelly. They fed dogs with food containing particles of carbon, maintaining anæsthesia

by intra-tracheal insufflation. Vomiting was excited by apomorphine, but none of the vomit entered the air passages, nor was the anæsthesia interfered with in any way.

Mr. Boyle's apparatus* is figured and described below. Another and useful form of apparatus has been suggested by Dr. H. H. Janeway,† and with it the method has proved successful in a large number of cases.



[FIG. 48.—Mr. Boyle's apparatus.

Air is driven from the bellows A, through hot water in the bottle C (the tap B is for air, and BI is a reserve tap for oxygen if necessary). The air then passes through E, over the surface of the ether in the smaller bottle, and so on to the gum-elastic catheter F. When it is desirable to give air without ether, E, E' are turned off and G is turned on. By regulating these taps it is quite easy to have either the whole or part of the air laden with ether vapour. The manometer D registers the pressure under which the air is driven into the trachea.

Dr. Boothby and Dr. Cotton use nitrous oxide and oxygen by the intra-tracheal route, and insist upon the importance of warming the gases before they enter the lungs.‡

The value of this method has been now established, although it had not escaped severe criticism. It is difficult for those

* See *Lancet*, Nov. 30, 1912.

† *Annals of Surgery*, Aug. 1912.

‡ *Boston Med. and Surg. Jour.*, 1912, vol. i. p. 486.

who have no special skill to acquire the knack of passing the catheter, and roughness may cause some trouble about the larynx, indeed, œdema and after-pain have been noticed. These drawbacks are obviously not due to the method, and can be obviated.

Interstitial emphysema again cannot occur if a safety valve is in use and periodic partial collapse of the lungs is practised. Although the most complicated operations upon the thoracic viscera have been performed upon dogs and upon human beings the periodic partial collapse of the lungs, the necessity of which has been mentioned, does not appear to have caused any inconvenience to the operator. The absence of respiratory movements has made the method a valuable one for abdominal sections. It may be pointed out that when such an apparatus is at hand it supplies the best means of ventilating the lungs with or without oxygen in cases in which respiratory collapse has occurred.

D. RECTAL ETHERISATION.—COLONIC ANÆSTHETISATION.

Pirogoff and Roux as early as 1847 suggested that ether should be given by the rectum, and finding that liquid ether could not with impunity be injected (Magendie), the former employed an apparatus which permitted only ether vapour to enter. Pirogoff obtained such good results that he believed rectal etherisation would replace pulmonary inhalation. More recently Dr. Axel Yversen of Copenhagen, Dr. O. Wanscher of the same city, and Dr. Mollière of Lyons, as well as Drs. Bull and Weir of New York, have tried rectal etherisation, and have spoken in favourable terms of it.

I have used the method extensively since 1885 and have found it to answer admirably for operations about the mouth, nose and post-buccal cavities, for intra- and extra-laryngeal operations, for staphylorrhaphy and for operations for the relief of empyema. For the removal of the tongue, for excision of the jaw, or jaws, and for plastic operations about the face, the method gives great facilities and freedom to the operator. Mr. Appleby recommends

the method also for prolonged dental operations. The advantages claimed are (i.) less ether is used, (ii.) recovery is more rapid, (iii.) after effects are less severe, (iv.) the stage of excitement is lessened or abrogated.

More recent advances in the technique of anæsthesia such as dosimetric methods of chloroform administration, and the intra-venous and intra-tracheal plans of introducing ether, have at the present time removed many of the difficulties in dealing with anæsthesia in oro-nasal and laryngeal operations, so that the rectal route has lost some of its claims for adoption in these cases. It remains, however, as a valuable alternative for some patients for whom other methods are open to serious objection.

Its disadvantages are:—the greater length of time the patient usually takes to become ready for operation. Although this objection is not applicable to all cases, I have found it expedient to shorten the time of induction by giving ether or chloroform in the usual manner through the air passages, trusting to rectal etherisation for the maintenance of anæsthesia. Besides saving time this plan lessens the actual quantity of ether required and so minimises the chance of deleterious after effects, and also preserves the patient from the discomforts of the induction when performed by rectal etherisation. Dr. Wanschier, however, says some of his patients, having been anæsthetised first by the usual method and subsequently by the rectum, preferred the latter. Dr. Bernard Stedman employed rectal etherisation in a series of cases adopting my method, and has reported most favourably upon it.

In some instances severe meteorism, diarrhœa, and even melæna have resulted. Unquestionably the method requires the greatest care and some experience before a uniformly happy result can be expected, and the anæsthetist must remember that carelessness in permitting too rapid an evolution of the vapour will lead to grave suffering if not to danger and death.

The apparatus I have employed is in effect an ether receiver holding about 2 or 3 ounces; this is plunged into a second vessel which should contain water at 120° F. The ether vessel communicates by an indiarubber tube

with a glass interceptor devised to prevent the entrance of liquid ether into the rectum. The farther end of the interceptor is joined by another and shorter tube to an anal tube. This is made for me by Messrs. Mayer and Meltzer. Some persons have employed the water at a higher temperature, but my experience leads me to believe that the untoward experiences which have been recorded have in most, if not all, cases been brought about by having the



FIG. 49.—Dr. Dudley Buxton's apparatus for administering ether per rectum.

water too hot, and so permitting a too rapid passage of ether vapour.

The use of my intercepting drip chamber is of great importance as it catches any condensed ether vapour, and prevents the passage of liquid ether into the bowel. My apparatus has been copied by various persons, and they have by omitting this drip chamber vitiated the whole apparatus, and rendered their patients liable to proctitis and other dangers.

The usual signs of anæsthesia are present, and so nothing need be said about them. As a rule children go under more rapidly than adults, when ether is given by the rectum, but the time occupied in inducing complete anæsthesia varies within wide limits. I have succeeded in 3 minutes and have had to wait 15 or 30 minutes. Dr. Stimson informs me that American surgeons have had several fatalities in employing this method. I have met with grave complications which, although in part due to the physical condition of the patients, were undoubtedly not wholly independent of the irritation caused in the intestines by the entrance of ether vapour.

A fatality which occurred after the performance of laryngectomy when the rectal method was carried out by me was believed to have been the result of the ether. The death, however, was sudden heart failure from collapse, and presented none of the signs of danger usual when rectal etherisation causes death. As no autopsy was performed it was impossible to prove the actual cause of death. As a rule fatalities, unless due to rapid paralytic distention or rupture of the large intestine, do not occur suddenly.

The administration.—The actual steps to be taken after anæsthesia is produced by inhalation are simple, although the management of the case imposes upon the administrator the necessity for great vigilance and judgment to avoid the undesirable extremes of too much or too little ether vapour finding its way into the bowel. There are certain important preliminaries to the method. The colon must be carefully emptied and prepared by large enemas for some days before the operation; a hypodermic of morphine and atropine alone or with scopolamine should be given one hour and a half before the operation. Whether anæsthesia has been produced by the oro-nasal route or not, the rectal tube is gently inserted and the warmed ether vapour allowed to bubble into the bowel. The rubber pad is kept pressed firmly against the perinæum by a diaper, but as one of the first effects of the ether is often to cause an accumulation of flatus in the lower colon it is wise to partly withdraw the tube and allow the gas to escape. I have had an escape tube closed by a tap introduced into the apparatus to facilitate this escape without

disturbing the apparatus, but this is not shown in the figure. As a rule little struggling occurs, and if present is easily controlled. When the mucous membrane of the bowel is accustomed to the ether, the amount of anæsthetic can be increased. The breath of the patient will smell of ether within a minute or two of the commencement of the procedure. As soon as complete anæsthesia is present, the amount of ether is to be lessened. This is done by lifting the ether chamber out of the water chamber.

This last must from time to time be re-filled as the water soon cools. It is wise to palpate the abdomen occasionally, and if undue distention occurs the supply of ether must be checked and any rectal flatus allowed to escape. Dr. Cunningham* and Dr. Dumont of Bern, the latter of whom has adopted my apparatus, have advocated the method and have met with success in its application. The former's procedure differs from mine. He drives air through ether and introduces the mixture into the bowel. The obvious objection to this is that the bowel is more distended even if a return current is arranged for by having an ingress and an egress tube. It may be pointed out that, by a very simple development of the apparatus figured, an electric warmer can be added, thus enabling the anæsthetist to control by a switch the temperature of the water in the warming chamber.

After effects.—Colicky pains in the intestines, urgent tenesmus, diarrhœa, sometimes dysenteric in character, painful distention of the intestinal tract with more or less severe collapse, are the complications which have been recorded. Deaths have occurred.

The treatment is to be conducted upon general principles, opium forming the most useful therapeutic ally. For their prevention the most important points needing attention are avoidance of the method in cases with a history of past intestinal catarrh or dysenteric attacks, and great care that during the administration no liquid ether is allowed to enter the rectum.

* *Boston Med. and Surg. Jour.*, April 20, 1905.

COLONIC ETHERISATION.

Dr. Arnd has adopted the method of introducing, per rectum, a stream of a 5 per cent. solution of ether in warmed saline, and my friend Mr. Flemming, of Bristol, has tried this plan with some success. A preliminary hypodermic injection of alkaloids is given. In Arnd's cases diarrhoea followed the procedure, but the stools were free from blood. I cannot speak from any personal experience of this plan, but my knowledge of the vapour method would cause me to be suspicious of introducing ether into the bowel in a liquid solution. Further evidence may prove this criticism is based on incomplete knowledge.

Dr. Gwathmey, as a result of some very interesting experiments, has shown that if ether is mixed with oil (carron oil is best) in a proportion of 50 per cent. and introduced into the bowel by means of a catheter anæsthesia results. For human beings he has used a 75 per cent. of ether and finds no injurious results follow.

E. INTRA-MUSCULAR INJECTIONS OF ETHER.

Walther * has attempted to anæsthetise patients by injecting ether into their buttocks. He used 45 c.c. up to 8 c.c., and states he obtained satisfactory results. An anæsthetic given by inhalation was used to hasten the effect. Slight convulsion, and ecchymosis followed the injection. Dr. Descarpentries speaks favourably of this procedure, although his experience is at present limited. Other observers who have tried the method have failed to obtain anæsthesia, although very large quantities of the anæsthetic were injected, so that one can hardly recommend this procedure.

Complications during Ether Narcosis.

The chief complications are connected with **respiration**. In the first place in persons whose lower jaw is underhung the mandible with the tongue is liable to fall back and so interfere with respiration. The fingers placed behind the

* *Bull. Medical*, May 29, 1912.

angles of the jaw will readily rectify this, but it is important to see that the lower teeth are not engaged behind the upper but project well beyond them in front ; to effect this the mouth must be opened and the jaw pushed forward, and when the lower teeth have advanced in front of the upper the mandible is kept in that position. The breathing may be stopped by a more serious cause through obstruction in the larynx, the rima glottidis becoming closed and no air entering the lungs. In some cases the rigidity of the masseter muscles may cause impediment to air entry by provoking tight closure of the teeth. Inspiration through the nose is very commonly imperfect through some stenotic condition, and it may be greatly hindered or prevented by the nostrils being sucked in with inspiration, whilst the lips at the same time are drawn in over the clenched teeth. In this way little air can enter the chest and the patient becomes cyanosed. If the teeth be forcibly separated by a mouth-opener, air will enter freely and the cyanosis pass off. It is wise in these cases to insert a gag between the teeth before replacing the inhaler. A towel wrapped round the face-piece and lower portion of the face will prevent an undue entrance of air. **Laryngeal spasm**, leading to partial or complete closure of the rima glottidis, may arise ; it is in most cases due to the impact of too concentrated ether vapour upon the sensitive laryngeal mucous membrane, but is especially liable to occur if cyanosis has been allowed to arise. In cases in which the trachea is displaced or pressed upon by inflammatory swelling, such as in angina Ludovici or by morbid growths such as goitres or masses of lymphadenomatous glands, if ether is incautiously given, laryngeal spasm and asphyxia are peculiarly likely to occur. Intubation, if possible, or perfusion with oxygen, offers about the only means available in such cases. Laryngeal spasm more commonly occurs when there is pre-existing hyper-æsthesia of the mucous membrane, *e.g.* in inflammatory conditions. Commonly the spasm is initiated by an attack of coughing, then the inspiration becomes stridulous and the patient grows cyanotic. It is usually sufficient to withdraw the ether until the spasm passes off and then administer the anæsthetic more guardedly. In very extreme cases it might be necessary to perform laryngotomy. The danger is

accentuated in short, thick-necked persons, and in those who through inflammatory or other causes suffer from pressure upon the trachea. In one case of which I have notes, laryngotomy was actually commenced, but fortunately I was able to force oxygen into the lungs and normal respiration was restored. Chloroform was then substituted for ether. In this case there was no evidence before the ether was given to cause suspicion that it would prove an undesirable anæsthetic. The movements of respiration do not cease in the condition of laryngeal spasm, whether partial or complete.



FIG. 50.—Mouth tube for edentulous cases.*

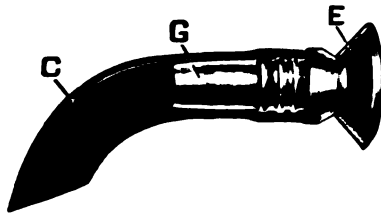


FIG. 51.—Section of mouth tube.*

In edentulous persons the long flabby lips are sucked in and act as a kind of valve permitting expiration but hindering inspiration. To remedy this the jaws should be separated by a Ferguson's gag; it is then easy to administer the ether as the gag keeps the mouth open and the lips apart. In figures 50 and 51 is shown a device originated by Sir Frederic Hewitt for use in edentulous cases. The metal end E is placed between the gums in the front of the mouth, and the rubber tube lies over the tongue to the region of the epiglottis. This contrivance maintains a patent

* I am indebted to Dr. Ferguson of East Orange for these figures of his modification of Sir F. Hewitt's mouth tube.

air way in such cases, but unless great care is taken the rubber tube is liable to get out of position and so become useless.

A more troublesome, although fortunately rare, complication occurs when the thorax becomes fixed by spasmodic contraction of the muscles of respiration. The treatment here is to maintain the air way patent, and to attempt to overcome spasm by artificial respiration. Jerking up the chin will by dragging the larynx upwards and forwards often induce the patient to take a deep inspiration. In spasmodic fixation of the thorax, abdominal respiration must be practised, and the floating ribs compressed in expiration. Stimulation of the nasal mucous membrane will sometimes initiate a deep inspiration. This can be done with quills of bibulous paper soaked in sal volatile or an ammoniacal solution.

Laborde's plan of rhythmic traction upon the tongue twenty times in a minute will prove valuable if the above fails. Freudenthal* suggests direct irritation of the epiglottis, and avers this gives better results than Laborde's plan.

When a slight degree of spasm of this kind follows coughing and irregular breathing, replacing the ether by chloroform for a few respirations will often completely remove all trouble. In all conditions the danger is increased by the rapidly deepening cyanosis. If the air ways can be rendered patent, and this usually can be accomplished by the means mentioned above, oxygen given under pressure as from a cylinder of compressed gas will greatly facilitate recovery. Intubation and perflation with oxygen are practically always possible, and seldom, if ever, fail to restore the function of respiration.

Mucus or excessive salivary secretion, by collecting about the epiglottis and laryngeal chink, sometimes sets up spasm and considerably interferes with respiration. I have met with one case in which a brief administration of ether for examination led to a most dangerous condition owing to the large amount of fluid secreted in the air passages. Inversion, tongue-traction and mopping out the pharynx eventually removed the obstruction to respiration and terminated successfully what was a most alarming experience. Such cases emphasise the value of the plan I now invariably adopt of injecting atropine an

* See *New York Medical Journal*, Dec. 10, 1898.

hour before administering ether. The same danger may arise from some blood effused during the operation, or from epistaxis, and these conditions must be borne in mind. Hæmoptysis and hæmatemesis are less liable to occur during the administration of ether than afterwards, but I have met with the former condition more than once. Placing the head well over to the side and sponging out the pharynx usually remove both the cause and the dyspnœa. In persons whose faucial isthmus is narrowed, and in those whose respiration under ether is not free, the tongue is liable to grow congested, venous return being hampered, and the swelling thus caused becomes a further factor in interfering with breathing. Opening the mouth, drawing the tongue forwards, and maintaining an adequate supply of air usually will remedy these difficulties.

Less important inconveniences of ether inhalation are the increased secretion from the mouth and respiratory tract; these, although interfering with respiration, are seldom of any great importance. Hölscher* has pointed out that râles heard in the trachea are due not to the secretion arising from irritation of the broncho-tracheal mucous membrane, but to aspiration of mucus and saliva from the mouth. It must be remembered, however, that in infants and weakly persons this excessive secretion may prove a grave complication, and cause blocking of the tubes and water-logging of the lungs.

Coughing occurs in many persons, especially if ether vapour be given in too concentrated a form; but it is not always necessary to remove the inhaler to remedy this, for frequently while a dry cough comes on in the earlier stages of etherisation, it is suppressed by pushing the anæsthetic. I have met with some cases in which cough has been very urgent, and associated with inspiratory dyspnœa and cyanosis so severe as to be alarming. In such cases some spasm usually exists. Inhaling oxygen will as a rule completely and rapidly remedy this condition, or a few whiffs of chloroform may be given.

The danger of **aspirating foreign bodies** into the air passages is of course present when the patient is under ether just as when he is under any other anæsthetic, but no detailed

* "Archiv. f. Klin. Chir.," B. 57, 1898.

notice need be given here, as this complication is considered at length elsewhere. A caution may be given about sponges and gauze mops inserted in the mouth during operations. These, when full of blood, are difficult to recognise unless secured by a ligature. A case occurred in a provincial town of death under ether, when, after respiratory failure, artificial respiration was actually performed, although a sponge placed in the mouth had slipped back and occluded the upper opening of the larynx. It had been forgotten, and only came to light during the post-mortem examination. If attention, however, is paid to the posture of the patient, so that the head is turned to one side, many of the dangers just referred to may be avoided or minimised.

Over-dose.—If ether be incautiously pushed for a prolonged period, without allowing the patient from time to time to renew the air in his lungs, the respiration may stop altogether. This condition would appear to ensue upon the overloading of the blood with ether, leading to poisoning of the respiratory centre. The treatment is the immediate performance of artificial respiration. If this be properly done the blood soon becomes duly oxygenated, and the nerve centres, being once more supplied with depurated blood, recover their control over the respiratory mechanism, and so natural respiration ensues. During very prolonged operations it is also wise to give ether sparingly during the last portion of the time, as when once the patient has been thoroughly narcotised by the anæsthetic he will remain unconscious for a considerable time without further inhalation. This is accentuated when narcotics such as morphine and its congeners have been injected. Indeed, whenever such drugs have been employed the anæsthetist will have to carefully limit the amount of ether given to avoid over-dose—moreover, little is required. When care is taken to avoid the patient growing at all cyanosed, over-dosage cannot occur. The danger incident to **over-stimulation** must be always in the mind of the administrator of ether. This anæsthetic is commonly selected for patients who are exhausted by disease or have to undergo some severe operation involving a grave degree of shock. The initial effect of ether is to provide stimulation, but this is done at the cost of still further exhaustion of the

nervous system, and unless the amount of stimulation is carefully limited to the recuperative power of the patient profound collapse will ensue as soon as the administration has ceased. The breathing will be gasping and shallow, often of a Cheyne-Stokes type, and the blood-pressure will fall to a dangerously low level, while the body temperature will also be materially depressed. To avoid such contingencies, strict ether limitation must be practised, oxygen given freely, saline infusion practised, and measures adopted to maintain and raise the temperature of the body. Some fatal results have followed the practice of holding an inhaler firmly over the patient's face and neglecting to allow him from time to time to breathe air.

Rarely, the **heart** may give trouble. In a few recorded cases fatal syncope has occurred at the commencement of ether inhalation, but whether such casualties can be justly imputed solely to ether influence is, I think, doubtful. Such cases are regarded by Professor Yandell Henderson as due to acapnia. The initial fear of the patient causes hyperpnœa, and this produces a lowering of the carbon dioxide content of the blood. Imperfect anæsthesia when this condition is present renders the patient liable to reflex cardiac inhibition, from which the heart fails to escape. If the patient struggles violently, as he is sure to do if the ether is given in too concentrated a vapour, he is liable to syncope from the strain imposed upon his heart.

Vomiting during the operation is nearly always due to the giving of too little ether, if the patient has been properly prepared, and follows upon the partial resumption of consciousness. The patient will be observed to inspire irregularly with shallow breaths, followed now and again by yawning inspirations. This will be succeeded by efforts at swallowing; rapid and chiefly abdominal inspirations ensue, and the patient retches and vomits. He grows pale, and the pulse becomes small, or even imperceptible, while the breathing grows intensely shallow. Conjunctival reflex returns just before the vomiting. In treatment, two indications are now paramount, to get rid of the vomited matter and to avoid any of it being drawn into the larynx by the deep inspiration which always follows the act of vomiting; secondly, to

prevent complete return to consciousness. To obviate these, the patient's head should be turned to one side without being raised, and all vomit removed with a sponge or by the finger; the inhaler or mask should be then rapidly re-applied; if further vomiting occur recourse must be had to similar manœuvres. But a judicious pushing of the anæsthetic at the first signs of the onset of vomiting will often, if not always, prevent the occurrence of sickness. In carrying out this plan great care must be taken, lest, if it fail and vomiting occur, the ejected matter should enter the windpipe.* If vomit be drawn into the trachea, and cannot be coughed up, it may be necessary to open that tube and take measures for the removal of the foreign bodies from the air passage. Aspiration of gastric and intestinal contents in cases of abdominal distention is liable to occur during anæsthesia. Many of the recorded deaths under ether have arisen from this cause, and the greatest care must be taken to avoid this complication by lavage, when that is possible and expedient, or by maintaining a sufficiently light narcosis to ensure laryngeal reflex persisting. The subject is, however, dealt with elsewhere and at greater length.

Ether tremor.—Occasionally patients during the induction of anæsthesia, and even when completely anæsthetised, evince this curious and inconvenient symptom. One or both legs shake and tremble, sometimes with great violence. If any attempt is made to control the movements, a clonus is set up and the condition made worse. The complication is not common, but I have met with it not infrequently. It occurs somewhat more commonly when ether is given by an open method, and is then more pronounced. These facts would seem to indicate that ether clonus is the result of light narcosis, and should therefore be remedied when a more profound degree has been obtained. It is sometimes possible to overcome it by deepening the narcosis or by changing the anæsthetic to chloroform.

* These rules apply only to patients who have been properly prepared for the anæsthetic. If it is not known whether the stomach is empty and vomiting threatens, it is best to encourage the sickness and then wash out the stomach before resuming the anæsthetisation.

AFTER EFFECTS OF ETHER.

These are **immediate** and **remote**. Ether chills the body, so that when the anæsthesia has to be kept up for any length of time it is advisable to keep the patient well covered up, and to apply hot-water bottles to his feet, thighs, and flanks. The arms and legs may also be bound up in cotton wool, especially when rectal etherisation is contemplated. The use of a hot-water table for prolonged and grave operations certainly counteracts this danger, as well as the shock.

The unpleasant taste and smell of ether often hang about a patient for hours. They are best got rid of by fresh air in warm and well-heated rooms in cold weather. The clothes should be changed and the mouth washed out with a solution of chlorate of potash, or other mouth wash. Whenever practicable a patient should be removed from the room in which the anæsthetic has been given as soon as the operation is completed.

The **post-operative dangers of ether** when **immediate** are due to :—

1. Interference with respiration.
2. Interference with circulation.
3. The occurrence of vomiting.

When **remote** they arise from :—

1. Inflammatory attacks affecting the mucous and serous membranes of the respiratory tract and pleuræ.
2. Failure of the circulation.
3. Rupture of vessels.
4. Renal complications.
5. Gastro-intestinal tract ; persistent vomiting (acidosis).

IMMEDIATE AFTER EFFECTS.

1. **Respiratory.**—Dyspnœa may arise from the posture in which the patient is placed after being put back to bed. Care should always be taken that the head is so arranged that respiration is unhampered and easy. Also, it must be borne in mind that vomiting may occur, and some one must be at hand to prevent suffocation from aspiration of

vomited matter into the trachea. An accumulation of mucus may hamper respiration after ether, for until the patient is sufficiently conscious he will be unable to cough away the cause of obstruction. Hæmoptysis rarely occurs, but I have seen slight cases on several occasions. When morphine has been given antecedently to the ether, the post-operative sleep is commonly very deep, the respirations are shallow, and if even slight additional obstruction to breathing arises due to malposition, mucus, blood, or vomit, the patient will, if unnoticed, become suffocated without giving any indication of his danger.

2. **Circulatory.**—Slight faintness may ensue after lifting the patient back to bed, but I have seldom seen trouble from this cause. In no case must the patient be allowed to sit up for some time after the senses have returned, as fatal syncope has occurred upon the patient sitting up to vomit.

3. **Vomiting** commonly sets in before the patient is fully conscious, but as a rule is slight, and soon passes off. When in bed he should have his head turned to one side. It is exceptional for a patient to vomit more than twice unless food has been taken too soon after the anæsthetic, or the patient has been imperfectly prepared for the operation. As soon as he is sufficiently conscious to swallow, he should be given a good drink of hot water in which has been dissolved bicarbonate of soda (ʒj to the Oj of water). Dr. Chandler* has pointed out that less sickness after anæsthetics occurs when the patients are placed in an almost sitting position as soon as they are returned to bed, and in this view I believe he is correct.

REMOTE AFTER EFFECTS.

These arise from irritation of the air passages, of the gastrointestinal tract, and of the renal mucous membrane set up by the ether.

1. **Respiratory.**—In a certain number of cases such complications occur, but I believe when ether is properly given it is rare to find bronchitis, broncho-pneumonia (so-called ether-pneumonia) following its administration. It has been

* "Surgery, Gynæcology, and Obstetrics," vol. iii. p. 580.

pointed out that pulmonary complications are most commonly found to arise in cases of abdominal section, and especially where septic conditions exist. In this statement probably lies the explanation of the occurrence of many cases of the so-called ether-pneumonia. Dr. Graham,* as a result of some very interesting experiments, has found that ether, when given freely, produces marked effects on phagocytosis. The power of phagocytosis may be lost for weeks, and consequent dangers ensue. This appears to arise through the avidity of ether for lecithin and other fatty materials. When olive oil is introduced into the rectum as soon as the etherisation is complete, phagocytosis returns within a few hours or so. Dr. Ferguson,† whose interesting monograph on the subject should be read, has adopted the plan of injecting olive oil $\frac{3}{4}$ v. (150 c.c.) as a routine measure as soon as an operation under ether has been brought to a conclusion. The infection of the lungs is, according to many observers, due to the aspiration of septic material from the abdomen which has found its way into the air passages. Hölscher's experiments, referred to above, show that aspiration from the mouth, where the pneumococcus is commonly found, can, quite independently of ether, introduce mucus and saliva into the trachea and bronchi. Whatever be the true pathogenesis of lung complications following ether inhalation, two facts are certain. Firstly, broncho-pneumonia does occur, although much more rarely than is commonly believed; and, secondly, complications are less liable to be produced when the anæsthetist limits the quantity of ether given, and avoids allowing a large amount of ether to enter the blood. In times before anæsthetics were employed, it must be borne in mind, pneumonia was a comparatively common complication of operations. And further, as ether is usually selected for the most desperate cases, it is used in cases in which pneumonia is most likely to develop. The lessening of phagocytic action no doubt plays an important part in the genesis of these sequelæ. It is further essential to remove as far as possible any source of infection

* *Jour. of Infectious Diseases*, 1911, vol. viii. p. 14.

† "Surgical Anæsthesia in its Relation to Immunity," *New York Med. Jour.*, May 11, 1912.

by disinfecting the teeth, the mouth, and the nose before the operation, and when possible to cleanse the mucous membrane of the stomach in cases of disease by preliminary lavage with a suitable antiseptic.

A mild attack of bronchitis is a not infrequent after effect. I have met with a case of pleurisy with pleuro-pneumonia, but as the condition was right-sided and occurred subsequently to an operation for the relief of hepatic abscess it may not have been due to ether. Bronchitis is especially liable to be caused in patients who have suffered from that disease previously, and in my experience seldom starts from ether chilling unless in the aged and asthenic. The danger of broncho-pneumonia and of true lobar pneumonia after ether is one about the frequency of which it is difficult to decide. Mr. Carter Braine* found the record of only one case of pneumonia in 4,380 administrations of ether, and in this case blood apparently entered the air passages during the operation. In the Report of the British Medical Association published in 1900 four cases were reported as pneumonia in about 6,000 administrations. None of these ended fatally, and some were trivial and rather instances of bronchitis than of true lobar pneumonia. I have been told repeatedly of cases of ether pneumonia which upon investigation I have found to be merely bronchitis, without any of the clinical aspects of the graver lesion. On the other hand, Dr. Drummond,† Dr. McCardie, and others, have published cases of pneumonia which apparently were due to prolonged etherisation. In a valuable discussion‡ this subject was carefully considered, the consensus of opinion being that true pneumonia is a rare complication of etherisation, provided the method adopted is one which prevents excessive quantities of the anæsthetic being taken. The association of pneumonia after ether with abdominal surgery is obviously one of importance, as the patients in these cases are at once liable to auto-infection, and to be placed in an unfavourable condition as regards pulmonary ventilation. If there is much bronchial secretion and the abdomen is tightly bandaged

* *Trans. Soc. Anest.*, vol. iii. p. 85.

† *Brit. Med. Jour.*, 1898, vol. ii. p. 939.

‡ See *Trans. of Soc. of Anest.*, vol. iii. pp. 55 and 69.

so that respiratory movements are limited the secretion cannot be got rid of and is extremely liable to act as a local irritant. It is, no doubt, this which after prolonged etherisation, especially when the anæsthetic is given freely, causes pulmonary trouble after ether. I am bound to say that in my own practice I have seen very few really severe pulmonary sequelæ to etherisation, but I have always restricted the quantity of ether employed in prolonged operations, and usually, when the condition of the patient permitted it, changed the anæsthetic to chloroform after half an hour or so. This precaution is especially needful if the patient shows signs of free bronchial secretion.

It is a significant fact that most pulmonary sequelæ of ether occur among hospital patients. Pneumonia seldom follows the inhalation of chloroform, as a recent writer has pointed out, but bronchitis certainly occurs as an after effect. But even admitting this statement, which probably no experienced anæsthetist will dispute, we are still left with the equally well authenticated fact that when the patient who has taken ether for a prolonged period is kept free from chills he seldom if ever suffers from pneumonia. As a practical outcome of the discussion it may be accepted that pneumonia is always a possible, although a rare, after effect of ether, and this liability must be reckoned with in making the choice of the anæsthetic and of the method of giving it. When the condition of the patient suggests pulmonary susceptibility ether had better be avoided. The use of atropine before giving ether must lessen the risk of post-operative pulmonary complications, if the views given above are correct, and certainly experience has shown that most atropinised patients have less bronchial irritation and less vomiting than those for whom atropine has not been prescribed. Dr. Pasteur in the annual oration before the Medical Society of London* considered this question and contended that most of the cases of abdominal operations which showed post-operative lung troubles were not pneumonic but were examples of "massive collapse" due to paralysis of the diaphragm and to other causes. His observations are of great value and go far to prove that ether-pneumonia is often

* *Trans. of Med. Soc.*, vol. xxxiv., 1911.

hurriedly diagnosed from symptoms which are really those due to another condition.

Another aspect of this subject is the infection of the patient by septic organisms from an ether inhaler. The possibility cannot be doubted when dirty instruments are used. Ether, however, is not favourable to the existence of pathogenic organisms. When an inhaler such as that figured on page 170 is used and the parts boiled or sterilised in carbolic acid solution this source of danger can be absolutely removed.

Although the treatment of these lung complications does not fall within the scope of this book, something may be said about prophylaxis. Bearing in mind that there is always a fall of some degrees of body temperature after taking an anæsthetic, it is most important that the patient should be warmly clad and that the room in which he is operated upon be kept at a proper temperature. Not less necessary is it that after the operation he should be always well covered up and carried into a room also heated, and care be taken that he is not chilled during the passage from one room to the other. Many persons lose their lives for want of this obvious precaution.

Acute œdema of the larynx and **œdema of the lungs** are both complications which have been described as associated with ether inhalation. They usually occur in persons who are suffering from some pathological conditions of their kidneys.

One of the gravest complications in ether narcosis is a **spasmodic condition** affecting the respiratory tract. Fortunately it is comparatively rare. It is not always associated with closure of the glottis, although the air passage is probably narrowed. The patient's respiration becomes shallow and cyanosis rapidly develops. This usually occurs after a paroxysm of coughing, and is not associated with an "over-dose" nor with a suddenly increased strength of vapour. The onset may be early in narcosis, or after the patient is completely anæsthetised. There are no signs of dyspnoea such as violent respiratory efforts, but merely fixation of the chest with cessation of the function of respiration. I have met with the condition in

short-necked stout persons and regard it as a vagal reflex. It is almost impossible to perform artificial respiration by the usual methods owing to the fixation of the thorax, but compression of the abdomen and rhythmic traction upon the tongue while oxygen under pressure is introduced into the lungs will counteract the spasm. Failing these measures the larynx would have to be opened, but I have fortunately never seen the necessity for this.

Profuse bronchial secretion, especially if the mucus is thick and tenacious, may cause trouble. In slight cases sponging the fauces and discontinuing the ether will be all that is required. In extreme cases when the lungs appear to be water-logged inversion and rhythmic traction upon the tongue will provoke a flow of mucus from the mouth and clear the lungs. The possibility of an acute œdema in such cases must be remembered.

When patients are operated upon in the Trendelenburg position they often grow markedly cyanotic and respiration is laboured and ineffectual, œdema of the eyelids and face may appear and the condition may grow serious through over-filling of the right side of the heart. Bleeding obtained by permitting some hæmorrhage is most valuable and diminution of the anæsthetic with free use of oxygen are indicated. Unless these measures combat the condition the posture must be corrected when the symptoms disappear unless some preliminary œdema is also present.

2. **Circulatory.—Ether collapse.**—After a very prolonged administration of ether, when large quantities are used, the patient may become dusky, the respirations shallow, the extremities cold, and the circulation poor. Especially is this liable to occur when the operation has been severe. Shock so arising, whether due to over-dosage with the anæsthetic, or to this coupled with surgical shock, is best treated by the feet-raised position, heat applied over the body and a sinapism on the pre-cordium.

Syncope or faintness following ether inhalation except as a concomitant of "collapse," or unless arising from persistent vomiting (*vide infra*), is very unusual and in my experience only occurs in the case of persons predisposed to syncope.

3. **Hæmorrhage** into the brain or medulla has been noted as a result of rupture of an artery after ether inhalation. It is not easy in such cases to eliminate coincidence, but cerebral hæmorrhage has certainly been found post mortem in cases of death under ether. On two occasions I have known this accident to happen to patients for whom I was to have given ether, but who died from the hæmorrhage a day or two before the operation was to take place, and so before any anæsthetic had been given. Had the hæmorrhage occurred during the etherisation the natural inference would have been drawn that it was the result of the ether inhalation.

Bearing in mind this danger and that of embolism it is certainly wise to avoid ether for subjects whose blood pressure is unduly high and who suffer from arterio-sclerosis, or from blocked veins.

4. **Renal complications.**—As had been pointed out above the most conflicting evidence has been advanced about the effects of ether upon the renal mucous membrane. Clinically many observers have noted more or less severe nephritis, hæmaturia, diminution, and even suppression of urine following the use of ether. Albuminuria not infrequently follows its use and when existent before the ether is taken it is commonly increased after the administration. My own experience is that when ether is carefully given renal complications are very exceptional, even albuminuria is unusual and suppression of urine most rare. I have used ether without untoward results following the inhalation when it was known that kidney disease existed. Still many careful observers have found such complications, and it would appear better to avoid the risk if there is no very cogent reason for the use of ether in the case.

5. **Gastro-intestinal tract.**

Nausea and **vomiting** in some cases may prove troublesome and very intractable. They usually occur in persons whose general health has been impaired before taking the anæsthetic. All food and stimulants must be withheld for three or four hours after ether, and the patient be encouraged to take teaspoonfuls of *hot water*; tepid water provokes more vomiting, hot water checks it. The use of metal spoons in

so administering the water should be avoided that the lips and tongue may not be blistered. I have found that when sipping hot water fails, a copious draught of it will often succeed. In some cases iced soda-water in sips is useful, while iced black coffee with a dose of bromide of sodium or of ammonia is often efficacious (gr. x. to a small cupful). Absolute quiet must be observed, the patient being placed in an airy room, with windows open, if the weather permit it. He should be well covered with blankets or rugs. In lesser degrees of sickness, sucking pieces of ice is useful; but the loading of the stomach with ice-cold water is a measure often followed by great sickness and discomfort. Covering the face with a thin handkerchief on which is dropped toilet vinegar will frequently check the tendency to sickness. Mackenrodt suggests cider vinegar used in this manner.

For persons known to be subject to severe ether sickness a dose of chlor.-butyl (gr. xv.) given one-and-a-half hours before the administration of ether is said to be useful. I have met with some success with this plan. Aspirin (gr. xv.) given by the bowel in saline is often successful, and when the subject is in a feeble state an ounce of glucose may be beneficially added to the saline in which the aspirin is mixed.

Should vomiting continue and there be accompanying collapse, iced dry champagne may be given in teaspoonful doses every quarter of an hour until improvement occurs. A mustard-leaf over the pit of the stomach will often prove beneficial. In persistent vomiting Kussmaul's method of lavage is recommended by Rhoades.* He introduces a Ewald's tube and syphons in and out warm boric acid lotion (gr. v. to ʒi.). When vomiting is feared rectal feeding for forty-eight hours should be adopted, and glucose be freely given as it maintains the strength and helps to break the vicious circle engendered by the exhaustion following the vomiting.

Some persons suffer from great nausea without much sickness. Small doses of tincture of nux vomica will do good in these cases; one minim in a teaspoonful of water, by preference hot, may be taken every ten minutes for an hour. This will generally check the nausea, and failing it, Dr. Ringer's suggestion of drop doses of *vinum ipecacuanhæ*

* *Therapeutic Gazette*, Oct. 1897.

may be tried. Dilute hydrocyanic acid in minim doses is also useful. Hæmatemesis has been recorded as having followed the use of ether. I have never met with a case of this, but I have seen several cases which appear to be of somewhat the same nature. After severe operations upon the stomach or intestines and occasionally after those upon the uterus, especially hysterectomies, the patient will vomit dark brown red material looking like digested beef-tea. It appears to be altered blood, but its source is doubtful. As a rule it disappears after general treatment and rectal feeding, but occasionally forms a symptom occurring in cases which terminate fatally. It is hard to resist suggesting some causal relation between this symptom and grave shock, even though the nexus is at present inexplicable. Stercoraceous vomiting occurring during and after operations for the relief of intestinal obstruction is considered later on.

Hiccough, which is sometimes very severe after ether, may be cured by mustard (ʒj. infused and added to ʒiv. of boiling water), taken in sips. Less unpleasant remedies are oil of cajuput, chloral hydrate, and morphine (administered hypodermically). A small cup of strong green tea, taken hot and without sugar or milk, will often check hiccough. The thirst, sometimes a troublesome result of ether inhalation, will frequently disappear if rectal injections of hot water or saline are given.

Diarrhœa and passage of blood per anum after rectal etherisation should be treated by emollient injections containing opium, while the general strength of the patient should be attended to, and his collapse treated upon general principles.

Coma.—Cases of glycosuria and pronounced albuminuric coma deepening and ending fatally have been recorded after etherisation. **Jaundice** persistent for weeks may occur, but is a rare complication; nor is it at all clear what relation the anæsthetic has to the condition unless ether has been given in too large a quantity. The treatment is conducted along usual lines.

DEATHS DURING ETHER NARCOSIS.

In the *Lancet* Report * seventy-nine deaths are quoted and particulars of the cases are given. The causes assigned may be summarised :—

Imperfect anæsthesia producing shock.—Asphyxia from blood, vomit, or regurgitated intestinal contents entering the trachea ; respiratory spasm ; bronchorrhœa.

Cerebral apoplexy in a case of senile degeneration of the arteries, embolism, "heart failure," "paralysis of the heart," heart failure during stage of excitement with struggling.

Pulmonary conditions.—Bronchitis in an emphysematous patient, congestion of the lungs, pleurisy with effusion, pneumonia, pulmonary œdema, diphtheritic laryngitis, and emphysema.

Renal conditions.—Uræmia, "from pre-existing kidney disease."

The autopsy in these cases showed the most common lesions to have been chronic disease of the lungs (mainly emphysema), of the kidneys, and of the heart. In several cases death resulted from mechanical asphyxia ; one from pressure of a goitre, one in which undigested food became wedged behind the larynx, and several of fæcal material passing into the lungs of patients suffering from intestinal obstruction. In another case, an ether adapted only for local anæsthesia was inhaled with a fatal result. As would be expected, many of the deaths attributed to ether were those of patients who were *in extremis* at the time of the operation, and for whom ether had been selected in order to supply some stimulant to counteract the profoundly collapsed state. There is very little doubt that none of the cases reported were deaths from overdosing with ether. There were several cases in which anæsthesia was clearly never obtained and death from shock took place ; while in most of the cases the choice of the anæsthetic appears to have been a faulty one. There can be no doubt in the mind of any experienced anæsthetist that in cases of pre-existing respiratory embarrassment (*e.g.*, goitre), in chronic lung disease, in advanced renal disease, and when the arteries are old and rigid, the use of ether may easily produce fatal

* *Op. cit.*, p. 165.

results such as are mentioned in the Report above cited. In the Report of the British Medical Association * four deaths are recorded as definitely associated with the anæsthetic, and two more or less certainly classified. Death was due in two cases to aspiration of stercoraceous material into the lungs. In the third case syncope occurred in a feeble anæmic woman lying on her left side. The heart failure occurred as the kidney was being manipulated, and was coincident with vomiting. The fourth case was that of a man who was in an extremely grave condition and died before the commencement of the operation. Cerebral hæmorrhage and uræmia occurred respectively in the remaining two cases, but several days subsequent to the administration of the ether. Most of the deaths recorded by Gultz, in his statistics of deaths under ether in Germany, were attributed to pneumonia, but as has been pointed out, many of the fatalities were, in fact, the result of auto-infection, and others were due to the injudicious methods adopted, by which excessive quantities of ether vapour flooded the lungs for prolonged periods.

Cases of death occurring during ether anæsthesia have been reported which are stated to have been caused through "status lymphaticus," but as such fatalities appear common to every form of anæsthetic no special mention need be made of them in this chapter. The condition itself is fully dealt with in the chapter devoted to the dangers and complications of anæsthesia (*vide infra*).

* *Op. cit.*, pp. 61 and 64.

CHAPTER V.

CHLOROFORM.

Chemical and physical properties.—Chloroform, trichloromethane (CHCl_3), is a colourless transparent liquid with a specific gravity of 1.527. When quite pure it is unstable and a small quantity of alcohol is always added as a preservative; 0.5 per cent. or 1 per cent. of absolute alcohol is usually added, lowering the sp. gr. to from 1.490 to 1.495. It is soluble in water (1 in 200) and freely miscible with absolute alcohol, ether, benzine and oils. It has an agreeable ethereal odour and sweet burning taste. Its vapour is not combustible, but if mixed with alcohol and ignited it burns with a smoky flame having a greenish edge. It is very volatile, but although mixing freely with air, pure chloroform vapour can only exist at a temperature of 140° to 143.6° F. (60° to 62° C.). Thorpe gives the boiling point as 61.2° C. and its density at 0° C. as 1.5266 compared with water at the same temperature (Allen). When exposed for some time to light, chloroform splits up into chlorine and hydrochloric acid. Chloroform vapour diffused in a hot room when illuminating gas or an open fire is burning decomposes, and suffocating fumes are liberated. I have noticed that this decomposition occurs when a powerful electric lamp is held over the chloroform inhaler. These fumes are composed of carbon oxychloride, COCl_2 (phosgene gas), and are always formed when chloroform is decomposed by light or heat in the presence of moisture. To test-paper chloroform should be absolutely neutral.

TRADE VARIETIES.

Three varieties of chloroform are well known in commerce, prepared respectively from duty-paid rectified spirit, industrial methylated spirit, and acetone. When carefully purified the three varieties cannot be distinguished by chemical tests, although the varieties prepared from rectified and methylated spirit are said to contain traces of ethyl chloride (Wade and Finnemore).^{*} Chloroform prepared from duty-paid rectified spirit costs about four times as much as that from acetone and about three times as much as that from industrial spirit.

Other varieties of chloroform in much smaller demand are chloroform prepared from chloral hydrate, which is naturally very expensive, and Pictet's chloroform, prepared by exposing pure chloroform to a temperature between -80°C. and -82°C. and removing the crystals of frozen chloroform from the surrounding fluid.

Commercial chloroform is usually fairly pure ; the following are the principal tests :—

Residue.—Ten c.c. evaporated in a shallow glass vessel on a water bath should leave no visible residue.

"Smell" Test.—When 10 c.c. are poured upon a filter paper and allowed to evaporate no foreign odour should be perceptible during the evaporation and when all the chloroform has volatilised, the filter paper should be quite odourless.

Free Acid, Chlorine, and Chlorides.—When 5 c.c. of chloroform are shaken for five minutes with 10 c.c. of distilled water and the upper aqueous layer is afterwards decanted from the undissolved chloroform, the watery layer should not redden blue litmus paper (absence of acid), it should not afford a blue colour when mixed with a few drops of dilute solution of cadmium iodide and mucilage of starch (absence of free chlorine), and another portion of the aqueous layer should not yield any turbidity on the addition of silver nitrate solution (absence of chlorides).

^{*} *Journal of Chemical Society*, July 1904, p. 938. See also *Trans. Soc. Anaesth.*, vol. vii. p. 89, where it is stated that the addition of 0.25 per cent. of ethyl chloride to acetone chloroform renders it physiologically identical with alcohol chloroform.

Chloroform should be kept in a cool, dark, place.

Dr. F. W. Tunnicliffe * has made some careful experiments with chloroform and chloroform residues to test whether their toxicity becomes increased, as a result of keeping, transport, etc. The specimens examined were taken out to South Africa and subsequently sent to England, where the examination took place. The conclusion arrived at was that when the chloroform is initially pure, except for the added alcohol, it remains free from pharmacological deterioration under the ordinary conditions of military transport. This, of course, assumes that the bottles which contain the chloroform are kept closely stoppered and protected from a strong light.

According to Sir William Ramsay, when chloroform is kept over slaked lime and decanted off before use it is kept pure. On the other hand, Mr. David Brown † asserts that contact with lime causes a rapid decomposition of chloroform. The addition of one per cent. of alcohol will, M. J. Regnaud believes, keep chloroform pure even if left exposed.

PHYSIOLOGICAL ACTION OF CHLOROFORM.

Harley pointed out that chloroform destroys the red corpuscles of blood. This may possibly, he thinks, explain the occasional supervention of jaundice after chloroform narcosis. I examined the blood in a large number of cases before and after the patients had taken chloroform, and found both a lessening of the number of red corpuscles and an actual increase in the number of white corpuscles. However, many other factors such as restriction of diet and loss of blood probably play some part in bringing about the result. It has been shown by Moore and Roaf ‡ that hæmoglobin and serum proteid possess the property of retaining chloroform in the blood, while Vernon Harcourt and Victor Horsley § have demonstrated that this is also true of the corpuscles. So long as they maintain their morpho-

* *Journal of the Royal Army Medical Corps*, vol. ii. No. 4, p. 459.

† *Pharmaceutical Journal*, Dec. 14, 1898.

‡ *Proc. Roy. Soc.*, vol. 73, p. 382

§ *Brit. Med. Jour.*, July 23, 1904.

logical integrity, they possess this property and are thus the active agents in conveying chloroform to the tissues of the body. It seems probable from the experiments of Moore and Røaf that chloroform when it has reached the tissues forms, what these observers term, an aggregation with the proteid constituents and so causes a gradual lessening of all biochemical activities, the extent of which is determined by the tension of the chloroform in the blood with which the tissues are brought into immediate contact. When this tension exceeds a definite limit not only is the power of function stayed, but the life of the protoplasm is destroyed. This catastrophe is hastened when the oxygen content of the blood is diminished, a fact which explains the signal danger of chloroform when associated with asphyxia.

Upon the blood corpuscles out of the body chloroform certainly acts as a solvent. It is a protoplasm poison rapidly destroying the contractility of muscle and the irritability of nerve tissues.

Prolonged inhalation of chloroform repeated day after day for a considerable time is said to lead to fatty degeneration of the tissues, and it is further asserted that like changes occur in a less marked degree even when but little of the narcotic is taken. Changes in the liver resembling those seen in acute yellow atrophy of that viscus, also swelling and subsequent destruction of the epithelium lining the tubules in the kidneys have been recorded. How far such destructive changes are due to absorption of excessive quantities of the anæsthetic, there is as yet no evidence to prove, although it seems probable that many of those who have experimented have failed to differentiate between chloroform employed as an anæsthetic in definite low percentage vapour and the toxæmia incident to chloroform introduced into the organism in high percentages. The author has considered this subject in a paper contributed to the Medical Society of London.*

Upon the skin and abraded surfaces, chloroform benumbs and acts as a strong irritant, and if evaporation of the condensed vapour be prevented causes vesication.

The various parts of the **nervous system** appear to become

* *Proc. Med. Soc.*, 1912, vol. xxxv. p. 280.

affected in the same order as obtains in the case of ether, the **cerebral centres** are influenced before the **sensory** fibres of the cord, these before the **motor** fibres, while last of all the **medulla oblongata** becomes paralysed.

Chloroform has been believed to possess a selective action upon the tissues of the nervous system, analysis of the tissues of persons who have been killed by chloroform showing that the brain and cord contain proportionately more of it than other tissues (Lallemand, Perrin, and Duroy). Julius Pohl has also found that the brain of narcotised subjects contains more chloroform than the blood taken from the afferent blood vessels. What is the nature of the action upon the nerve centres we are unable to say, but evidence points to the probability that it is exerted upon the tissues themselves. Hamilton Wright * has shown that the **neurons** are profoundly affected by both chloroform and ether, and the effect is proportionate to the duration of the inhalation. Marked, although evanescent, microscopic changes occur with rarefaction of the cell-substance which it is suggested may modify nervous function. The effects of anæsthetics upon isolated **nerve** have been carefully worked out by Waller. This observer has shown that, in the case of chloroform, the nerve tissue readily loses its electro-excitability, seven times more easily than in the case of ether, and is liable to be so permanently damaged as to lose it entirely.

It has been proved by Sherrington and Sowton, and by others, that chloroform exercises a direct influence upon all **muscular tissues**, although voluntary is less affected than involuntary muscle. The **muscular fibres** of the heart are, however, very sensitive to chloroform and rapidly lose their resiliency. This probably explains the **acute dilatation** of that organ described by Professor McWilliam. The action is proportionate to the strength of the chloroform vapour.

Chloroform, although possibly in part split up (Zeller), certainly remains mostly unchanged in the body and is eliminated in the urine, the breath, and the milk.

* *J. Phys.*, vol. 26, pp. 39 and 362.

PHYSIOLOGICAL EFFECTS OF THE INHALATION OF CHLOROFORM.

The effects produced vary considerably, according as weak or strong vapours are inspired. When two per cent. is inhaled the ordinary phenomena of anæsthesia occur, while stronger vapours produce death by the action of the chloroform upon the tissues. Dealing firstly with the physiological effects of dilute vapours, it is convenient to divide the period of narcosis into five degrees.* Of these the third represents anæsthesia and last two profound narcosis when respiration and circulation are failing or have failed. The last two degrees, however, require stronger vapours.

In the first degree—from commencement of inhalation to the impairment of consciousness—fulness in the head, singing, buzzing in the ears, palpitation of the heart, are sometimes felt; there is also some diminution of common sensation. The respiration is hurried, especially when the patient is nervous. The circulation is accelerated and the pulse may be at first fuller, but soon grows weaker. The pupils are sensitive to light and are moderately dilated, and the ocular globes move. The patient will look at you and follow with his eyes. The senses are confused, but the patient often will obey when spoken to loudly.

In the second degree the mental powers are impaired

* Snow divided the period of narcosis between initial inhalation of chloroform and death from its extended effect into five empirical degrees. He pointed out that anæsthesia occurred in the third degree and that any nomenclature which allowed the term anæsthesia to be qualified by such adjectives as complete, imperfect, and so on, introduced an undesirable ambiguity. If a patient is described as in the second degree of narcosis, every reader knows the precise physiological conditions present, whereas if he is said to be in a state of imperfect anæsthesia, no one except the narrator has any clear idea of what depth of narcosis was present except that it was below the third degree, since the patient was not anæsthetic. Similarly the "stage of excitement" equally well describes the second degree of narcosis and the condition of the patient as he is regaining consciousness and after he has passed through the third and even the fourth degrees of narcosis, so that its use although condoned by custom must be recognised as being not only unscientific but misleading. Of course Snow's degrees must merge one with another, but the clinical phenomena which characterise them are quite definite, and so they can be differentiated one from another, and mark epochs in the patient's progress. French physiologists, however, restrict themselves to three degrees, thus introducing fresh complications.

although not suspended. The patient at first remains passive as if sleeping, or occasionally makes a semi-voluntary movement. Sometimes laughing, singing, talking, are indulged in. Snow believed that dreaming occurs at this time and then only. When more deeply narcotised the patient becomes restless, he attempts to remove the face-piece or inhaler, for he is conscious of being inconvenienced by the vapour, but not of the necessity for remaining passive. Common sensation is much blunted, so that patients submit without expostulation to painful manipulation. This degree of narcosis is sufficient in parturition, and the after stages of prolonged operations. As a rule, struggles or expressions of pain which show themselves at this time are not remembered subsequently. The respiration and circulation are both quickened, the former being rendered more shallow and at times interfered with by contractions of the skeletal muscles and of the diaphragm. Spasm of these muscles may occur, accentuating this cause of respiratory disturbance. The pulse, accelerated at first, towards the close of this degree drops to or below the normal rhythm and is weakened in force, and blood pressure falls. The ocular globes remain movable, the light reflex persists and the pupils are dilated. Salivation and a desire to expectorate are commonly present. This degree of narcosis is frequently profound enough for the performance of operations upon children, who even if they move slightly are unaware of what is being done to them. It is, however, never wise to operate until the third degree of narcosis has been attained.

In the third degree all voluntary movements are lost and complete anæsthesia is present. The conjunctival vessels become full, the muscles rigid, and struggles, even epileptiform convulsions, may supervene, but only at the time the second is merging into the third degree. As the narcosis becomes deeper the muscles relax, and inarticulate jabbering and mouthing cease. Although really insensitive to pain, the patient may in the early part of this degree wrinkle his forehead, flinch, or even cry out. Later, reflex acts are abolished, the conjunctival and nasal receding late. The patella jerk persists for some time, while under deep anæsthesia the ankle-joint phenomenon appears in some cases.

The rectal reflex influence upon the respiration will often be present throughout this degree of anæsthesia. The respiration and circulation settle down to the normal, or even grow distinctly weaker, and some pallor may be seen and blood pressure is markedly lowered. The buccal muscles ceasing to act, the cheeks are blown out during expiration, the chin drops, through the weight of the tongue, and interference with breathing may result from falling back of the tongue towards the laryngeal aperture. The ocular globes now become fixed, and although the light reaction persists the conjunctival reflex is completely lost. The pupil contracts and remains smaller than normal. The lower lid no longer travels upwards to protect the globe as it does in the lighter degrees of narcosis when the upper lid is lifted.* In rare cases the skin shows a slight rash like that seen in ether narcosis, but it rapidly disappears, leaving the skin cold and pale.

The fourth degree.—At this period the patient is profoundly unconscious and in extreme danger; the centres controlling respiration and circulation in the medulla oblongata are unduly narcotised and respiration and circulation enfeebled. Such deep narcosis is seldom needed, save for the reduction of old-standing dislocations, in deep dissections, and in the case of alcoholics, and necessitates the use of a strong vapour.

It is marked by corpse-like flaccidity of the muscles, pallid or bluish skin, deep stertorous breathing gradually growing difficult, irregular, shallow, and unduly diaphragmatic, while the pulse is quick, compressible, and feeble, becoming almost imperceptible. The blood pressure again sinks until the heart is unable to carry on the circulation. The ocular globes are fixed, the pupils are widely dilated and no longer react to light. This degree corresponds to increasing paresis of the centres in the floor of the fourth ventricle.

The fifth degree is the interval which, following the fourth degree of narcosis, intervenes between the respiratory embarrassment and total cessation of breathing. Even after dyspnœa has been succeeded by cessation of respiration the

* This is a valuable sign which I have observed and is no doubt of the protective reflex type.

heart may beat feebly for a brief time, the circulation growing more weak and the heart eventually stopping, although if examined it will be seen to evince fibrillary contractions. In this degree the centres in the medulla' oblongata are completely narcotised and no longer able to conduct or control the essential processes of life. Gradually failing respiration culminating in its complete cessation, followed by complete failure of the circulation with paralytic dilatation of the heart, wide dilatation of the pupils, extrusion of fæces and urine, mark this final and fatal degree of narcosis.

The phenomena described as occurring in the degrees of narcosis vary somewhat in different persons. In the alcoholic, for example, the excitement is very marked and prolonged. These persons may remain restless, their muscles being rigid and movements occurring even when they appear to be completely under the influence of the anæsthetic. Neurotic people also are prone to move and appear restless; their respiration and circulation may be, and commonly are, adversely affected by reflex influences even when the usual signs of anæsthesia are present.

It may be convenient to consider more in detail the phenomena which appear as the patient passes through these degrees of narcosis. The divisions mentioned are of course artificial, and merge insensibly one into another; but the physiological effects which the inhalation of chloroform produces are continuous and vary directly as the strength of chloroform vapour which reaches the lungs.

The effects on the circulation of the blood.—The arterial pressure is said to undergo an initial rise, but the rise, if it occurs at all, which many observers doubt, is commonly slight, and is due, if we accept the experimental work of Gaskell and Shore, to an initial stimulation of the vaso-motor centres. This is followed at once by a gradual fall of blood pressure. Schäfer and Scharlieb, who have re-investigated the action of chloroform upon the heart and blood vessels, regard chloroform as a vaso-constrictor. The later fall of blood pressure, they believe, is due to progressive weakening of the heart muscle.

Embley and Martin, relying upon their investigations upon the circulation of the kidneys and small intestines, have come to the conclusion that although vaso-constriction results from

high percentages of chloroform, yet if the percentages are kept at or below the level which is possible when the vapour is inhaled, vaso-dilatation invariably results, and as a consequence depletion of the arterial system and filling of the venous system occur.

The pulse of the patient is quickened as he commences to inhale and slightly increased in force, but it rapidly grows less full and may become markedly feeble. The fall in blood pressure is admitted by all competent authorities, but the interpretation of its cause is matter of dispute. McWilliam has shown that as soon as chloroform enters the blood, and its absorption by the pulmonary vessels is extremely rapid, it is conveyed through the coronary vessels to the heart muscle. The result is evidenced by weakening of the action of that organ as it gradually loses its contractility and finally undergoes paralytic dilatation. The more recent research of Sherrington and Sowton has made it clear that even very small quantities of chloroform act at once upon the heart muscle, but provided that the amount of the anæsthetic does not exceed a certain limit the muscle accommodates itself to the chloroform, and its force of beat, although lessened, is not unduly diminished. When, however, the percentage dose of chloroform is increased, and the limit is a narrow one, the heart muscle becomes paralysed and is irrecoverable. The weakening of the cardiac contractions undoubtedly leads to a fall in the blood pressure. As a result the nerve centres, like the heart muscle itself, become deprived of their proper blood supply and cease to maintain the regulating mechanism of the blood circulation. Leonard Hill, in the course of his valuable work on this subject, has shown that when the central nervous system is deprived of its due supply of blood it is more readily affected by chloroform, as indeed by all narcotic poisons. A percentage which will not prejudice the nerve centres of a person whose blood pressure is normal, will prove fatal when the blood pressure has undergone declension. And not only does this occur, but as a result the tonus of the whole arterial system becomes damaged or destroyed, and the blood drains from the arteries into the veins. The force of gravity which in the physiological state assists the circulation now causes the blood to accumulate in

the large veins of the abdomen (the abdominal pool of Hill) and the circulation comes to a standstill. The truth of these statements has been called in question by the meritorious work of the Second Hyderabad Commission due to the splendid zeal and enthusiasm of Lieut.-Col. Lawrie, but it must now be admitted that all physiologists are agreed upon the matter and claim that the tracings published by the Hyderabad Commission themselves demonstrate the gradual weakening of the heart under the influence of chloroform. The great merit of the work done by the Hyderabad Commission—and its value cannot be over-estimated—undoubtedly is the abundant proof that the experiments afford of the dangers of obstructed respiration. Although primary heart failure probably does occur in any degree of chloroform narcosis—but this the Commission denies—yet one of the commonest causes of death under chloroform is interference with respiration through over-dosage and secondary failure of circulation. Leonard Hill, however, has indicated that although this reasoning is apparently correct, yet, as a matter of fact, the sequence of events is a vicious circle. The patient inhales an over-dose of chloroform, an over-dose usually due to too high a concentration of the vapour, so that the blood pressure falls in spite of a possible initial rise due to asphyxia, and the respiratory centre ceases to receive its proper supply of blood. Then comes respiratory embarrassment and ultimately fatal interference with circulation.

The mechanism by which this "primary heart failure" occurs has been described by Leonard Hill and may be given in his words:—"Concentrated vapour of chloroform is presented to the respiratory orifice, the nerve endings of the sensory fibres of the vagus in the respiratory tract are powerfully excited. The animal struggles, the glottis is closed, and by the violent contraction of muscles the intra-thoracic pressure is raised. . . . The effect of raising the intra-thoracic pressure is to diminish the output from the right heart, to congest the venous system and lower the arterial tension; the lungs are also compressed and to a great extent emptied of blood. Blood supply to the coronary arteries is diminished; this is due to the fall of arterial tension. The oxygen in the

blood is decreased owing to the prolonged holding of the breath. By these means the nutrition of the heart is impaired. Finally, owing to the excitation of the respiratory centres caused by the asphyxial blood, the animal is forced to take two or three deep inspirations. The lungs are immediately surcharged with chloroform vapour, and the blood reaches the coronary arteries carrying a dose of chloroform sufficient to throw the heart into paralytic dilatation." Syncope occurring thus early in the inhalation appears to explain a large number of fatalities under chloroform which have been recorded. It is usually reported that "the patient struggled, became suddenly pale, the heart stopping, and after giving one or two gasps, died without showing any response to artificial respiration." As has been justly pointed out by Lawrie, such deaths ought never to occur if the administrator is watching the respiration and as soon as any holding of the breath occurs withdraws the chloroform until the breathing becomes natural. Sherrington has shown that provided the concentration has not been too great, recovery will take place, since blood pressure has not fallen too much and the heart muscle has not undergone the "paralytic dilatation" of McWilliam. The initial fault is, of course, using too concentrated a vapour, and what often happens is that one deep inspiration of the concentrated vapour is taken, and this in many subjects suffering from a dilated or feeble heart may prove fatal. It cannot be too strongly insisted upon that it is not so much the quantity of chloroform taken as the degree of concentration of the vapour inhaled, which leads to the fatal result.

A further consideration with regard to primary syncope under chloroform is the danger of syncope due to fear.

In the days when anæsthetics were not commonly used, death before the operation was not unusual and was attributed to fear. A similar experience is at the present time to be met with during the use of local analgesia. The patients in many cases, although suffering no pain, vomit and faint from the emotion of seeing and hearing the steps of the operations upon their bodies. Now, with respect to fear-syncope under chloroform, it might be supposed that the chloroform inhalation was merely a coincidence with the syncope, if it were not

for the fact that such cases of fear-syncope are extremely rare, if they ever occur, under ether. Probably, the depressant action of the chloroform on the one hand, leading to weakening of the heart beat with fall of blood pressure, and the stimulating effect of ether on the other with the increased cardiac contraction, make all the difference in the ultimate issue of the case.

In the later degrees of chloroform narcosis syncope may arise from another cause. With the diminution of arterial tension and the progressive weakening of the respiration, due to the anæmia of the medulla oblongata arising from the falling blood pressure, the chloroform still enters the lungs and is conveyed to the circulation. There is no undue concentration of vapour in the ordinary sense, although the continuous inhalation of the vapour of the particular concentration leads to overloading of the blood with chloroform, and to slow but progressive fall in arterial tension. As the respiratory centre becomes anæmic it is more readily paralysed by even a small quantity of the narcotic, and finally is unable to carry on its functions. When the respiration progressively fails, so does the circulation grow feebler and finally ceases. But this gradual syncope is, according to Hill, not the result either of respiratory failure or asphyxia. After respiratory failure, if the heart is still able to contract, as a rule, the patient can be restored when artificial respiration is carried out. In the sudden failure of circulation arising from paralytic dilatation of the heart no resuscitative measures are of much avail. It may again be pointed out that even here *watching the respiration*, if thoroughly done, would safeguard the patient, especially if, as should always be done, the degree of pallor of the lips be observed. Whether accumulation of chloroform can take place in the blood even when a comparatively dilute vapour is being inhaled, is at present open to question, but it seems at least probable that accumulation in a certain sense does occur. Vernon Harcourt's investigations appear to prove that, during prolonged inhalation of chloroform, the expired air at first contains more than half the amount of chloroform inspired; later, a larger quantity is given off, and when the anæsthetic is given in lower percentage the expired air may contain more than that inspired. It is

blood is decreased owing to the prolonged holding of the breath. By these means the nutrition of the heart is impaired. Finally, owing to the excitation of the respiratory centres caused by the asphyxial blood, the animal is forced to take two or three deep inspirations. The lungs are immediately surcharged with chloroform vapour, and the blood reaches the coronary arteries carrying a dose of chloroform sufficient to throw the heart into paralytic dilatation." Syncope occurring thus early in the inhalation appears to explain a large number of fatalities under chloroform which have been recorded. It is usually reported that "the patient struggled, became suddenly pale, the heart stopping, and after giving one or two gasps, died without showing any response to artificial respiration." As has been justly pointed out by Lawrie, such deaths ought never to occur if the administrator is watching the respiration and as soon as any holding of the breath occurs withdraws the chloroform until the breathing becomes natural. Sherrington has shown that provided the concentration has not been too great, recovery will take place, since blood pressure has not fallen too much and the heart muscle has not undergone the "paralytic dilatation" of McWilliam. The initial fault is, of course, using too concentrated a vapour, and what often happens is that one deep inspiration of the concentrated vapour is taken, and this in many subjects suffering from a dilated or feeble heart may prove fatal. It cannot be too strongly insisted upon that it is not so much the quantity of chloroform taken as the degree of concentration of the vapour inhaled, which leads to the fatal result.

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the force of expiration gradually fails during prolonged chloroform inhalation, and so if the expired air does not eliminate sufficient chloroform vapour a gradually deepening degree of narcosis must occur. This takes place so slowly that only the greatest care enables the administrator during a protracted operation to recognise the over-narcotism. In the emphysematous, expiration being ineffectually performed, even from the first, there is an especial risk of this. And again during protracted operations, when bleeding is severe, the lessened quantity of the blood in the body will make a much smaller dose of chloroform sufficient to paralyse the medullary centres. Struggling plays an important part in bringing about syncope under chloroform in the period corresponding to the first two degrees of narcosis. It increases the liability to an augmented intake of chloroform and by causing fixation of the thorax raises the intra-thoracic pressure, and so puts a severe strain upon the heart as well as interfering generally with the mechanism of circulation. Such interference must tell with especial force upon the cerebral circulation. The effect of posture also is one of primary importance upon the determination of syncope. As Hill has shown, when the vaso-motor system is rendered paralytic by chloroform the "stopcock action" of the capillary system ceases to work, and, as a result, the arteries at once empty themselves of blood. The force of gravity, when the vaso-motor system is intact, assists circulation, otherwise it favours the accumulation of the blood in the veins. Under these circumstances, when the person is placed in the feet down posture the brain and medulla at once empty of blood and the medullary centres being anæmic can no longer energise. Several deaths have occurred of persons who, during a recovery from profound narcosis, either have been lifted or have risen into the sitting position and have at once fainted and died.

We know further that the vagus nerve mechanism plays an important part in the causation of death under chloroform. Embley, who has investigated the question of fatalities in the early degrees of narcosis, and Schäfer with Scharlieb, who have studied the effects of chloroform upon the arteries and

heart, come to conclusions which may be briefly summarised. The vagus nerve mechanism when influenced by chloroform rapidly obtains an increased power of inhibition over the heart. As we have shown, the anæsthetic by causing acute dilatation of the heart directly weakens it and brings about a fall of blood pressure. It is this declension of arterial tension which renders the heart less able to escape from the vagus control, and inhibition partial or complete ensues. With cessation of the heart's action the blood pressure falls to zero and respiration stops. Embley has proved that this dangerous inhibition is liable to occur in the case of the lower animals whenever the strength of the chloroform vapour in the air inspired rises above 2 per cent. Whether, as has been suggested, the vagal action is exercised reflexly through nerve endings in the nasal, laryngeal, or pulmonary areas is open to some question, although it seems probable. It is certain, however, that the theory of such reflex mechanism is insufficient to cover the whole ground. For when all reflexes are experimentally eliminated, vagal inhibition still occurs and is then due to the hyperactivity of the vagus nerve mechanism and is induced by the chloroform in the blood stream. This is a danger of the induction period, for when that is safely surmounted the vagus action ceases to make itself felt, its excitability having become depressed. It is liable, however, to be excited again by increasing the strength of the vapour of chloroform, or by asphyxia. The degree of readiness with which this can be done depends upon the duration of the administration and the endurance of the vagi.

Respiratory system.—As soon as the initial excitement has passed off, the force of the respiratory movements is lessened. The thoracic excursion is obviously lessened as inhalation proceeds. What are the alterations in the gaseous exchanges during light and deep narcosis we have yet to learn, but that they become progressively less, there is every reason to believe.

To understand the mechanism of chloroform narcosis the following facts should be considered :—

Chloroform vapour enters the blood until an equilibrium is established between the tensions of chloroform in the

alveolar air of the lungs and that in the blood itself. So long as the tension in the air is maintained equal to or above that in the blood, no chloroform can leave the latter through the agency of the pulmonary mucous membrane. Snow demonstrated this theoretical assertion by actual experiment, substantiating the truth of the *a priori* statement, and so he arrived at the following law :—" As the proportion of vapour in the air breathed is to the proportion that the air, or the space occupied by it, would contain if saturated at the temperature of the blood, so is the proportion of vapour absorbed into the blood to the proportion the blood would dissolve."

The amount of vapour which can be taken up (held in suspension) by the air of the atmosphere, varies with the elastic tension of the chloroform vapour at different temperatures. Thus at 40° F. a small quantity of chloroform would evaporate into air ; at 130° F. so much would volatilise as to give rise to an almost pure chloroform vapour. Snow's results, given below, were obtained by less exact methods than are now possible. His facts and inferences have been substantiated to a great extent by others, and by recent researches.

One grain of chloroform in one hundred cubic inches of air produces the second degree of narcosis, but never carries chloroformisation further. This corresponds to a proportion of one part, by measure, of chloroform in 16,285 parts blood, or 0·0000614 the proportion by weight. Two grains in each hundred cubic inches of air, or $\frac{1}{28}$ saturation (unity being saturation), produces the fourth degree of narcosis, or 0·0001228 the proportion by weight.

Two grains or more in the hundred causes interference with respiration ; three grains in the hundred seems about the ratio which renders respiration impossible. Three grains represent 2·3 cubic inches vapour, and as air at 100° F. can take up 43·3 per cent. of its volume, the blood must contain from $\frac{1}{18}$ to $\frac{1}{15}$ of the proportion it is capable of absorbing when the respiratory centres are poisoned.

The appended table (Snow)* shows at a glance the quantity

* "Anæsthetics," p. 33.

of vapour, in 100 cubic inches of the saturated mixture of vapour and air, at different temperatures :—

Degrees, F.	Air, per cent.	Vapour, per cent.
40 . . .	94 . . .	6
45 . . .	93 . . .	7
50 . . .	92 . . .	8
55 . . .	90 . . .	10
60 . . .	88 . . .	12
65 . . .	85 . . .	15
70 . . .	81 . . .	19
75 . . .	78 . . .	22
80 . . .	74 . . .	26
85 . . .	70 . . .	30
90 . . .	65 . . .	35

Snow found further, that calculating the weight of the blood as thirty pounds, twelve minims of chloroform in the circulation produces narcosis of the second degree ; eighteen minims would induce the third degree (surgical anæsthesia) ; twenty-four deep narcosis (fourth degree) ; and thirty-six paralysis of the medullary centres. In practice more is needed because a certain proportion evaporates from the tracheal and bronchial surfaces and is carried out in expiration. If twelve minims be evaporated into a bladder and inhaled to and fro, no more air being allowed than can be blown through the lungs, narcosis of the second degree actually results. Now, taking thirty-six minims as a lethal dose, the following considerations, upon which Snow strongly insisted, explain how easily this quantity may enter the circulation if the administrator be not perpetually upon his guard against over-dosage ; 18 minims represent the amount absorbed to produce surgical narcosis, this amount might be absorbed by the use of 36 minims, the remaining 18 minims being exhaled as above mentioned. These 36 minims make 37·5 cubic inches of vapour, and at 60° F. may exist in combination with 257 cubic inches of air, making it expand to nearly 300 cubic inches. The 300 cubic inches would be inspired in twelve respirations of 25 cubic inches. Now, if a vapour of this strength were continuously inhaled,

the residual and complemental air would become saturated, and as about 250 cubic inches represent the air in the lungs, this amount would at 60° F. contain the vapour of 30 minims. Assuming only half this quantity to be absorbed, that is 15 minims, we should then have 18 + 15 or 33 minims in the blood, an amount almost if not quite enough to paralyse the respiratory centre. These points being held in remembrance will explain many cases of chloroform death, ascribed to "idiosyncrasy" or the "fatty heart."

The lesson which these facts appears to the writer to emphasise is, that chloroform to be used with safety must be employed in low percentages. If we translate Snow's figures into percentages we find that he and Paul Bert agree in fixing a 2 per cent. as the strength of vapour which produces the third or anæsthetic degree of narcosis. Double this and we reach the quantity which kills. The problem is no doubt a complex one when chloroform is administered to a patient, but there is little, if any, doubt that there exists a very narrow margin of safety when we transcend the 2 per cent., and that unless we are prepared to run a considerable risk we must keep within this percentage.

These considerations, which cannot be studied too carefully, point out the importance both of avoiding an over-dose of chloroform, and of maintaining a due elimination of the drug. The Hyderabad Commissions again and again urged the grave dangers which follow when asphyxia (by which is meant impediment to thorough air exchange in the lungs) is permitted to complicate chloroform narcosis. Such asphyxia of course means impaired elimination, itself tantamount to accumulation of chloroform in the blood. Broadly speaking, it is true to say that a dose of chloroform which is safe, provided due air exchange is ensured, rapidly grows dangerous when its elimination is interfered with. It is thus evidently a fallacy to urge that if only a small quantity of chloroform is given, the patient is free from danger. The peril lies not in the quantity of chloroform inspired when breathing remains unimpeded, but in the strength of the vapour entering the lungs. In this sense breath holding and lowered blood pressure may, it has been alleged, be accepted as safeguards, since on the one hand the intake of

the vapour is stopped, and on the other the deportation of the chloroformed blood is lessened. But, inasmuch as the holding of the breath is always followed by one or more vigorous inspirations, which convey large, often fatally large, quantities of chloroform to the medulla, while a lowered blood pressure and feebly acting heart depress the vitality of the tissues and render the medullary centres more prone to be poisoned, and also increase the danger from vagal inhibition, these conditions are really fraught with grave danger to the chloroformed patient.* And further, even though breath holding may hinder for a moment the additional intake of chloroform vapour, it will in no way prevent the blood from taking up all the chloroform which has already entered the lungs, and this increase in the chloroform tension, since there is no elimination, must make for that over-dosage which the breath holding is assumed to prevent.

THE ADMINISTRATION OF CHLOROFORM.

Many methods have been proposed. They may be classed as (1) those requiring the use of some apparatus or inhaler and (2) those in which chloroform is given by dropping it upon a towel, handkerchief, lint, etc. In this second class the various plans adopted are commonly grouped under the heading of "The Open Method," although as will appear from the sequel, while some of the modes of procedure are truly "open," some are not more "open" than when the use of an inhaler is adopted.

1. **Inhalers.**—Among the first designed to supply a definite percentage vapour of chloroform were those of Snow,† Clover,‡ Sansom,§ Squire, and Junker.|| All of which, except the last, have passed into desuetude. Junker's inhaler has, at the present time, undergone many and important modifications.

* A careful research upon the chemical changes produced in the organs and tissues by the inhalation of chloroform will be found in "Physiologie Travaux du Laboratoire du Ch. Richet," p. 413, 1898, by Dr. Vidal.

† "On Anæsthetics," p. 81.

‡ *Medical Times and Gazette*, Aug. 9, 1862

§ "On Chloroform," p. 127.

|| *Medical Times and Gazette*, 1867, vol. ii., p. 590.

There is no doubt that the principle which these instruments were constructed to carry out, viz., the regulation in definite proportions of the quantity of chloroform inhaled, is the correct one. No method, indeed, which does not enable the administrator to adopt this principle is a safe or reliable one. Inhalers which supply more or less exactly a definite percentage of chloroform vapour to air are those of Dr. Raphael Dubois, Mr. Vernon Harcourt, Dr. Levy,* Professor Waller, and the Roth-Dräger apparatus.†

DOSIMETRIC INHALERS.

THE DUBOIS APPARATUS.†

This apparatus delivers a definite percentage vapour to the patient, who thus, at any given time, breathes a known strength of chloroform vapour diffused in air. The strength of the vapour inhaled is independent of the force and frequency of the respirations. Whatever percentage is deemed requisite for the patient is easily obtained by a simple mechanical arrangement. As the apparatus is heavy it is placed upon a firm table near the couch on which the patient lies. It consists of a container to which a definite quantity of chloroform is supplied, a spirit lamp evaporates the vapour, and this vapour is carried with a definite quantity of air through a tube to the face-piece. The apparatus is worked by a handle, and this when turned initiates the mechanism by which the chloroform vapour and air are commingled and carried forward to the patient. By a simple device the strength of the vapour delivered can be varied. Thus when the patient has entered the third degree of narcosis the percentage of chloroform is decreased. If for any reason it is desired to produce a more profound anæsthesia the percentage is increased. Although Dubois' apparatus has been employed mainly in the physiological laboratory, it possesses great value as a clinical

* *Lancet*, May 27, 1905.

† These and other apparatus are described and criticised in the Report of the Special Chloroform Commission of the British Medical Association, issued in 1911, and published by the British Medical Association at 1s.

‡ For a full description of the apparatus see *Anesthésie Physiologie*. By Dr. Raphael Dubois, Paris, 1894, p. 106, *et. seq.*

instrument and has been shown to give excellent results in various hospitals in which it has been tried. The type at present in use is slightly modified from that originally designed, but the principle remains the same. The principle being on the "plenum" system satisfies those who regard it as safer when the patient inspires from an atmosphere driven to the face-piece by a motor or bellows—*i.e.* respiration from a filled space or plenum rather than when a patient inspires the vapour by the mechanical effort of respiration.

The experience of Dr. Waller and Dr. Paul Chapman of Hereford, the latter of whom has used the Dubois anæsthesiometer in many cases, fully proves that this apparatus has a practical value. It delivers 2 per cent. vapour as its maximum.

THE VERNON HARCOURT REGULATOR.*

The Vernon Harcourt chloroform regulator is designed to enable the anæsthetist to retain complete control of the strength of vapour which the patient inhales. This instrument in its present form is the outcome of the painstaking labours of Mr. Vernon Harcourt, collaborating with the Special Chloroform Committee (B.M.A.), to which he was co-opted a member. The regulator supplied the essentials for a dosimetric inhaler capable of giving definite percentages of chloroform and yet being wholly under the control of the anæsthetist. After prolonged investigation it was accepted as satisfactory by the Committee.

DESCRIPTION OF THE APPARATUS.

The Harcourt inhaler supplies, in sufficient quantity for full respiration, a mixture of air and chloroform vapour which is automatically limited to a maximum strength of 2 per cent., and can be diluted at will with additional air down to any lower percentage.

Into the two-necked bottle chloroform is poured to near

* See *British Medical Journal*, July 18, 1903; also *British Gynecological Journal*, May 1904, "Chloroform in Surgical Anæsthesia, the Vernon Harcourt Inhaler," for papers by the present writer dealing at length with the practical and clinical aspects of this invention. The apparatus is made by Messrs. Griffin & Co., of Kingsway, London.

the top of the conical part as shown in figure 54, and two coloured glass beads are dropped into the liquid to indicate when the temperature is within the range 16° – 18° C. If the



FIG. 52.—The Vernon Harcourt chloroform regulator. The index indicates 1 per cent.

The inhaler is shown fixed to a stand with an arrangement for warming the chloroform.

temperature of the chloroform is below 16° both the coloured beads will float ; if it is above 18° both will sink ; in the former case the proportion of chloroform inhaled will be less than the pointer of the stopcock indicates ; in the latter case it will be greater. The proportion is also increased by any agitation of the bottle. During inhalation the chloroform is cooled by evaporation ; its temperature can, however, be kept between 16° and 18° by now and then holding the bottle in the hand till the blue bead has sunk and the red bead is beginning to sink. When the inhaler is mounted upon a stand the temperature of the chloroform can



FIG. 53.—Two-necked bottle for chloroform.

be kept at the required height by a movable stand supporting either a hot-water bath or a spirit lamp separated from the bottle by a wire gauge. Even a "night-light" will supply the requisite heat. The dimensions of the bottle have been arrived at after a great deal of experimental work and careful analysis. The diameter of the upper portion has been proportioned to the average rate of human respiration and to the rate of evaporation of chloroform between 16° and

18° C.* To compensate for varying rates of respiration the inlet and outlet of the bottle are placed near together and at

* The first apparatus was graduated for the temperature 13° to 15° C., but for ordinary use it is better to have the bulbs made to indicate the temperature mentioned above, otherwise the percentage is liable to fall too low.

some distance from the surface of the liquid, while to compensate for the lowering of the liquid surface by evaporation the vessel widens as the surface of the chloroform descends. The nearness of the two necks one to another, and the distance between them and the surface of the chloroform, diminish the variation in the proportion of inhaled air to chloroform vapour which is caused by abnormally shallow or deep breathing. When the flow of air is gentle, much of it passes in at one neck and out at the other without reaching the surface of the chloroform or displacing wholly the mixture of air and chloroform which occupies the upper half of the bottle. On the other hand,



FIG. 54.—Pointer adjusted to give 2 per cent.



FIG. 55.—Pointer adjusted to give 1.4 per cent.

the strong current caused by deep breathing draws out all the vapour which has been formed and promotes further evaporation by stirring the surface of the liquid. With bottles of the present dimensions this correction is only partial. If the rate of breathing is voluntarily reduced to 3 litres a minute instead of the normal 4 or 5 litres, or raised to 7 or 8 litres a minute, the proportion of chloroform may be raised to about 2.5, or lowered to about 1.5 per cent. It would not be difficult by lengthening the cylindrical part of the bottle to correct more completely for variations in the rate of breathing. But it is believed to be advantageous that the proportion of

chloroform should vary thus, in order that there should be less variation in the total quantity of chloroform administered. Two ratios have to be considered in judging of the probable effect upon a patient, that of chloroform vapour to air, and that of the mass of chloroform inhaled to the mass of the body through which it is distributed.

The stopcock is made so that when the pointer is at the end of the arc nearest the bottle of chloroform the maximum quantity is being administered—namely, 2 per cent. When the pointer is at the opposite end only air will be inhaled; and when it is midway dilution of the 2 per cent. mixture with an equal volume of air will make the proportion 1 per cent. The shorter lines on either side indicate intermediate quantities—namely, 0·8, 0·6, 0·4, 0·2 per cent.; and towards the chloroform bottle, 1·2, 1·4, 1·6, 1·8 per cent.

The valves on the two branches prevent the entrance into the apparatus of expired air, and also serve to show whether the stopcock is working correctly. Only one valve opens when the pointer is at either end of the scale, both equally when the pointer is midway, and for all other positions one valve opens more and the other less, in the degree indicated by the position of the pointer on the scale. The movement of these valves shows also how full and regular the breathing is, and the slight click which they make conveys this information to the ears when the eyes are otherwise occupied.

It is generally found that beginning with the pointer at 0·2 per cent., and moving it on towards the chloroform bottle, at the rate of one division about every half-minute up to 1·6 per cent. or 1·8 per cent., produces narcosis as quickly as is desirable.

For the maintenance of narcosis it is found that 1 per cent. or even less will be sufficient. The stopcock can be moved by a touch of the finger so as to increase or diminish the percentage.

If by fall of temperature, or agitation of the bottle, the yield of chloroform is diminished, or increased, this may be allowed for at once by a movement of the stopcock.

The face-piece is provided with an **expiratory valve** unless the valve is fixed on the upright stem of the inhaler (Plate V.).

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be increased. The indications for this are the appearance of the face and supervention of shock.

As has been pointed out that shaking of the chloroform bottle varies the rate and force of breathing alter to an appreciable extent the actual amount of chloroform inhaled. Shaking of the bottle need never occur, especially if the bottle is removed from the patient's face while he is lifted from the operating-table, or when his posture has to be changed during the operation. The variations in the rhythm of respiration occur chiefly during the induction, and in these cases give rise to no difficulty. In using this, as in the case of any inhaler, the anæsthetist must of course be guided by the usual signs of chloroform narcosis, and when this is reached the indicator should be turned to 1 per cent., whatever strength of vapour seems desirable. It cannot be too strongly insisted upon that the Vernon Harcourt indicator is only a means to an end. It supplies a fairly accurate method of regulating the percentage of chloroform admitted to the patient, but it does not, nor can any inhaler, obviate the necessity for a competent knowledge of the action of chloroform on the human subject and experience in administering that anæsthetic. *The apparatus need not, and must not, detach the chloroformist's attention from his patient's condition*; it merely enables him to increase or decrease the percentage of chloroform as may be necessary. Observation of the patient's condition will indicate when the necessity arises. When using the inhaler, care should be taken that there is accurate apposition of the mask to the face, otherwise the amount of vapour supplied will be below the necessary 2 per cent. and anaesthesia may result. A wet towel or roll of wet gauze will in some cases assist in securing air exclusion. This is laid over the patient's chin and folded up in the hand, holding the mask in such a way as to prevent air being sucked in around the air pad. The air pad should always be well inflated before use. It is also necessary to see that the valves are acting and the expiratory valve is not covered up. The inspiratory valves should be in a horizontal plane, and the whole apparatus placed out of the reach of the surgeon and his assistants.

Steadiness is certainly obtained by fixing the body of the apparatus to a stand placed on a table or fixed to the

PLATE V.



Vernon Harcourt chloroform regulator, to which is fixed a flexible tube connecting the inhaler with the face-piece, also oxygen connexion. The manner of holding the face-piece is indicated, and the position of the expiratory valve attached above the flexible tube and opposite oxygen inlet.

It is usually connected by about 20 inches of half-inch rubber tubing, the inhaler being supported on a stand, or attached to a sling passing round the neck of the administrator as shown in Plate V., or it can be attached to the back of the patient's bed.

The mask is made of solid toughened rubber, fitted with a rubber air cushion. In practice it is found advisable to

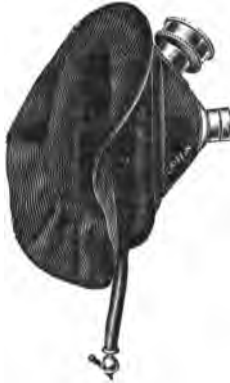


FIG. 56.—Flanged face-piece (Author's pattern).

nearly fill this air cushion with water, adding enough air to produce moderate distention. It can be washed, or placed in hot water, and as it then becomes plastic the shape can easily be modified, if required, so as better to fit the patient's face. I have had a flanged mask made (fig. 56) which materially facilitates keeping it accurately applied to the face and prevents inleakage of air.

Certain cases may occur in which a higher percentage is required than that afforded by the apparatus as above described. For increasing the strength of the vapour inhaled a tube (fig. 58) is provided which fits into the open neck of the bottle, raising the possible maximum dose to 2.5. At intermediate positions of the pointer the percentage will be increased in the same proportion as the maximum. Owing to the unavoidable limitations of accuracy imposed by the glass-blower's art the



FIG. 57.
Valve chamber.

ingress neck of the chloroform bottle is not absolutely uniform, so to correct this the most recent form of bottle is fitted with a metal collar fixed into the ingress neck which is quite true to scale.

No chloroform evaporates excepting that which is inhaled by the patient; and only that which is exhaled passes into the air of the room.

Use of the inhaler.—The apparatus must be carefully examined to see the parts are adjusted, and the administrator should inhale, or incline the instrument sideways, to see that the valves are working properly. About 2 oz. of chloroform should be poured in as high as the waist of the conical bottle and the beads introduced. The face mask should then be carefully applied. This is best done when the head is turned to one side. Breathing taking place freely and the air inlet valve and expiry valve working properly, the face-piece should be grasped with the left hand, while the lower jaw is pressed forward by the right hand placed behind its angle. Firm pressure is necessary, as absolute co-adapta-



FIG. 58.
Increase of per-
centage tube.

tion of the mask to the patient's face is essential. If the pressure used is equal over the whole area of the face the patient will not complain. It is a common fault to allow air to enter by the sides of the bridge of the nose. Absolute fitting of the face-piece having been secured, the strength of the vapour may be gradually increased by turning the pointer. This is done slowly, but, unless the patient is restless and struggles, not very slowly. Struggling is an indication for lessening the strength of the vapour, but not for the removal of the face-piece unless duskiness supervenes. When anæsthesia is attained, the usual signs being relied upon, its maintenance can be effected in most cases with 1·5, 1, or even ·5 per cent., according to the physique of the patient and the requirements of the operation. After prolonged administration slight duskiness may appear, and in this case the mask may be lifted for a few breaths and then replaced. A better plan, however, is to have a supply of oxygen (see Plate V.) which by a simple adjustment can enter the apparatus throughout the inhalation. Under ordinary circumstances a very small stream is required, but at times the amount given

should be increased. The indications for this are the appearance of the face and supervention of shock.

It has been pointed out that shaking of the chloroform bottle and variations in the rate and force of breathing alter to an appreciable extent the actual amount of chloroform inhaled. The shaking of the bottle need never occur, especially if the inhaler is removed from the patient's face while he is lifted on to the operating-table, or when his posture has to be changed during the operation. The variations in the rhythm of respiration occur chiefly during the induction, and in practice give rise to no difficulty. In using this, as in the case of any inhaler, the anæsthetist must of course be guided by the usual signs of chloroform narcosis, and when this is too profound the indicator should be turned to 1 per cent., or whatever strength of vapour seems desirable. It cannot be too strongly insisted upon that the Vernon Harcourt regulator is only a means to an end. It supplies a fairly accurate method of regulating the percentage of chloroform presented to the patient, but it does not, nor can any inhaler, abrogate the necessity for a competent knowledge of the action of chloroform on the human subject and experience in administering that anæsthetic. *The apparatus need not, and must not, detach the chloroformist's attention from his patient's condition*; it merely enables him to increase or decrease the dose of chloroform as may be necessary. Observation of the patient's condition will indicate when the necessity arises. In using the inhaler, care should be taken that there is accurate apposition of the mask to the face, otherwise the vapour supplied will be below the necessary 2 per cent. and failure may result. A wet towel or roll of wet gauze will in some cases assist in securing air exclusion. This is laid over the chin and folded up in the hand, holding the mask in such a way as to prevent air being sucked in around the air pad. The air pad should always be well inflated before use. It is also necessary to see that the valves are acting and the expiratory valve is not covered up. The inspiratory valves should be in a horizontal plane, and the whole apparatus placed out of the reach of the surgeon and his assistants.

Steadiness is certainly obtained by fixing the body of the apparatus to a stand placed on a table or fixed to the

operating-table, and connecting it as above by means of tubing with the face-pieces (see fig. 52). When the operation is on the neck or upper part of the trunk, it is better to have the expiratory valve fixed in a connexion joining the tube and face-piece with the vertical stem of the inhaler. This prevents exhalations passing over the area of operation. The valve aperture in the face-piece, if one exists, can be

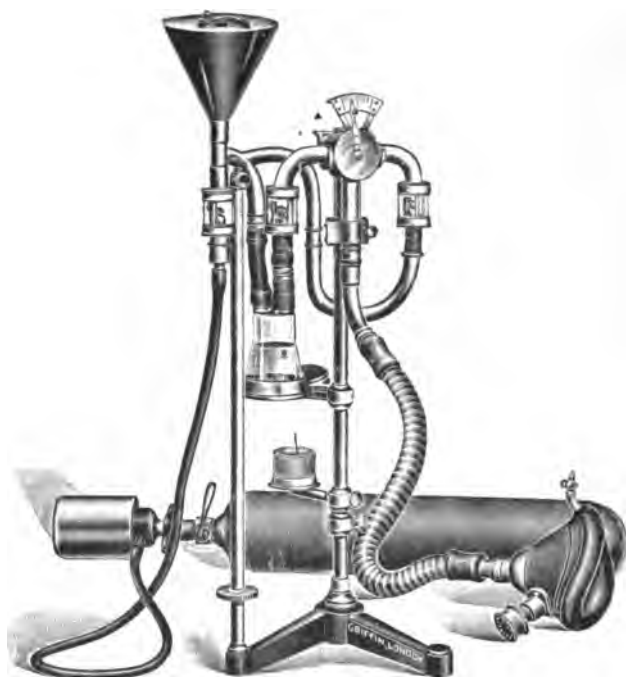


FIG. 59.—The Vernon Harcourt inhaler fitted with a constant supply of oxygen from a cylinder of compressed oxygen arranged as a "plenum" inhaler.

closed with a cork. This arrangement is shown in Plate V.).

I am fully convinced that oxygen should be employed whenever a general anæsthetic is in use, and this is especially true of chloroform when given for severe operations involving shock. It is to be used as an adjuvant and never to such an extent as to produce apnœa and so run the risk of provoking an acapnic condition. Mr. Harcourt has devised a somewhat

complicated addition to his regulator which permits a very free supply of oxygen. It is shown in fig. 59.

Such elaboration is, however, unnecessary as a tap fitted into the face-piece or metal connexion between the inhaler and the flexible tube leading to the face-piece answers every purpose. As *warmed* oxygen is far more efficacious the best plan is to allow the gas to pass from the cylinder into a worm of tubing through a warming chamber heated by water or an electric heater and then out through pressure tubing to its connexion with the inhaler. This plan allows air as well as oxygen to be breathed, a matter of importance. The entrance of oxygen lowers the percentage of chloroform vapour so that the increase tube may be requisite.

In operations upon the air passages propulsion of the chloroform and air mixture into the mouth or nose is necessary, and by attaching a large hand ball to the air-supply tube shown in figure 60, and substituting a mouth or nasal catheter for the face-piece, this can be effected.

This, of course, converts the inhaler into a "plenum" apparatus, since the patient no longer has to aspirate the vapour, it being forcibly propelled to the opening of his air passages.

Speaking from an experience of ten years, and some thousands of cases, many of the gravest character, I may say I have found the inhaler fulfils all the purposes for which it was constructed. It supplies a 2 per cent. vapour, although capable of giving a 2·5 per cent., but 2 per cent. in practically all cases will induce profound narcosis. It is easy to manage, and when the technique is once learned the apparatus proves reliable and satisfactory. There have been no dangerous symptoms due to the anæsthetic in the cases in which I have used the inhaler, and no failures. It has been increasingly rare for me to have to employ any percentage higher than

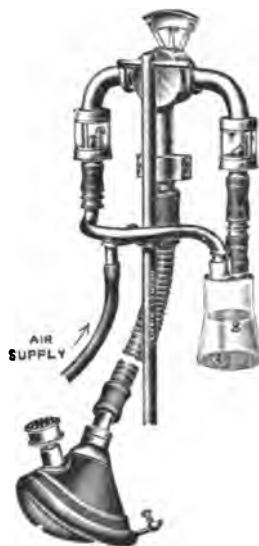


FIG. 60.—The Vernon Harcourt inhaler adapted for a "plenum" inhaler.

that afforded by the inhaler ; and even in the few instances in which I have replaced the inhaler by another, the necessity has usually arisen from the difficulty experienced in making the face-piece fit accurately.

DR. LEVY'S REGULATING INHALER.*

This, like the Vernon Harcourt regulator, is devised upon the "draw over" principle, but differs in several particulars, which may be summarised as follows :—

(i) The range of the available strength of vapour extends up to 4 per cent.

(ii) The principle of the water bath is applied to the regulation of the temperature of the chloroform, which therefore requires no active attention.

(iii) It is designed for use only when fixed to a table or other support, in order to obviate the possibility of any error arising from accidental agitation of the chloroform.

(iv) The percentages of vapour are accurately controlled even under the diverse conditions of draught consequent upon different types of breathing. A difficulty occurs under ordinary conditions of aspiration over a surface of chloroform, in that a slow current of air, such as would result from a faint inspiration, takes up a larger proportion of vapour than does that resulting from breathing of a more vigorous type. An adjustment is brought about in this instrument by applying a two-fold principle. Firstly, only a fraction of the inspired atmosphere passes through the chloroform container ; this vapour-laden portion is charged to a high percentage, and it naturally moves at a slower rate than would the total inspiration. Such fractions of inspirations exhibit relatively less change of composition for varied inspirations than would be the case if the whole of the inspired air passed over the chloroform. The complement of pure air is drawn through

* *Lancet*, May 27, 1905. Cf. *Medico-Chir. Soc. Trans.*, vol. 88, p. 673.

a large aperture which is permanently open, and in this way the percentages of vapour in the mixture are approximated. Secondly, the "chloroform current" traverses a series of tubes and passages, and in consequence undergoes a certain retardation which tends to be more pronounced during weak suction; the influx of pure air through a simple aperture not being retarded to the same extent, it follows that the dilution becomes greater during faint inspirations. This supplementary process supplies the finishing touch, which renders the percentages practically identical for all forces of suction commonly found under chloroform narcosis.

The body of the inhaler consists largely of a vessel which is filled with water at a temperature of 104° F., and the chloroform container forms a part of the cover of this vessel; the supply of air to the chloroform is controlled by a tap which is manipulated by an index hand, and the position of this indicates on a scale plate the percentage being delivered, a simple form of correction being applied for any temperature of water between 104° — 52° F. A length of wide-bore aluminium tubing and a double junction serve to connect the body with the face-piece. Two hinged aluminium valves, inspiratory and expiratory, complete the apparatus, which has generally been constructed with a view of presenting the least possible resistance to the passage of the inspired air.

II. PLENUM INHALERS.

The inhalers constructed upon the principle of mixing air with chloroform vapour in definite proportions, the air being driven through the chloroform and so presenting a vapour to the patient which he aspires, are best represented by Dubois' anæsthetic machine, by Dr. Waller's * balance inhaler, by the late Dr. Alcock's inhaler† and by the Roth Dräger inhaler. These supply definite percentages, and are more adapted for hospital practice. The Roth-Dräger

* *Trans. Roy. Med.-Chir. Soc.*, vol. 88, pp. 685 *et. seq.*; *Science Progress*, vol. ii., p. 621.

† *Brit. Med. Jour.*, Aug. 15, 1908, and Feb. 6, 1909.

possesses the advantage of mixing oxygen with the air and is a very useful, although elaborate, apparatus. It, however, can supply percentages of chloroform far above the safety limit, and in this may prove dangerous. There is attached to it an ether supply enabling the anæsthetist to use one or other or a combination of these anæsthetics at will. Junker's inhaler, constructed also upon the "plenum" system, is portable, but is only approximately accurate as a means of giving definite percentages, and its use is not free from



FIG. 61.—Mr. Hobday's electric motor apparatus for the administration of anæsthetics.

A, Electric motor. B, The fan and tube attachments. C, The contact breaker and regulator. D, The specially constructed bottle containing the anæsthetic. E, The inhaler. F, Wire to be attached to an electric lamp bracket or plug in wall. G, Switch.

danger. As is indicated above, the Vernon Harcourt regulator can be used as a plenum inhaler.

Mr. Hobday* has invented a very useful form of dosimetric chloroform inhaler which can be used for animals or human beings by supplying suitable face-pieces. Air is driven over chloroform kept at one level by a simple device, the strength of vapour being capable of exact adjustment. The grading has been carefully worked out by Mr. W. Legge Symes. I

* *Canine and Feline Surgery*, by F. R. G. Hobday, F.R.C.I.V.S., F.R.S.E., pp. 33 *et seq.*

have used this apparatus for dogs but not for human beings. It is at once simple and reliable. It is actuated by a motor.

JUNKER'S CHLOROFORM INHALER.

This **inhaler** has been modified by many persons. It was designed for use with "methylen," but now, as that agent is seldom employed, the apparatus is used for the exhibition of chloroform.

It consists of a glass bottle fitted with a metal mount on which is screwed a metal cap, and to this are attached two tubes, one for ingress of air, one for egress of chloroform vapour and air; a Richardson's hand ball-bellows and a vulcanite face-piece with tubes which connect the bottle with the bellows and face-piece. Half an ounce of chloroform is placed in the bottle, and the top screwed on. To the ingress hole is attached a long metal tube extending from the metal cap to below the level of the chloroform, so that when the ball-bellows is compressed, air passes down this tube and ascends through the chloroform taking up vapour. Finally the vapour escapes by the egress tube into the vulcanite facepiece from which the patient inhales.

In my original modification of this apparatus an ounce of chloroform is poured into a bottle* through a funnel-shaped opening fixed in a screw top. A foot bellows can be used, fixed by straps, one of which slips over the toes, while the other receives the heel in a long loop. When the foot



FIG. 62.
Glass face-piece (Dudley Buxton).

* The bottle I use is somewhat larger than the original pattern, as this gives the administrator a greater control over the chloroform. He can employ as dilute a vapour as possible, but can give a stronger one should occasion demand it. In the shorter bottles, if the upper surface of the chloroform is within a certain distance of the entry of the egress tube, liquid chloroform is forced up this tube. When this has once been done by vigorous compressions of the hand-bellows, syphon action is established and the contents of the bottle are pumped over, with dangerous results.

presses lightly, the air in the bellows is forced through the tube into the bottle, thence through another and shorter tube to a face-piece. The addition of the pressure ball is for equalising the stream of air and the avoidance of splashing, while it converts the intermittent into a constant supply of vapour. It is important not to put more than an ounce into the bottle at once, unless a large bottle is employed, and not to pump in air spasmodically or too forcibly, otherwise chloroform may be driven through the system of tubes into the face-piece. Even if this should not happen, a strong



FIG. 63.—Dudley Buxton's improved chloroform inhaler.

blast of chloroform-impregnated air is very unpleasant and deleterious if allowed to impinge upon the face. The longer tube in the bottle along which the entering air travels (afferent tube) should have its lower extremity tipped with some non-conductor of heat, such as wood or bone, to prevent freezing and blocking of the tube; and the exit tube (efferent tube) should be so constructed that in no position of the apparatus can liquid chloroform enter it. When the bottle has become nearly empty, the mill-headed stopper which closes the funnel is removed and more chloroform added; thus the apparatus need never be unhooked from the ad-

ministrator's coat, and the top never unscrewed until the administration is over, when the bottle should be emptied and cleaned.

In fig. 63 is shown the apparatus I have now employed for some years, and which I have found to answer better than any of the older patterns. It consists of a somewhat larger Junker's bottle than usually supplied. The Skinner's mask is replaced by a glass face-piece, to which is fixed a metal rim carrying the air supply tube, and this delivers into



FIG. 64.—Chloroform bottle for Junker's inhaler (Carter Braine).*

a perforated tube, running from back to front of the metal frame. There is a hinged rim which can be raised to allow a piece of lint or domett being placed over the opening on the upper aspect of the mask. When this rim is shut down it locks itself and keeps the lint in position. This apparatus can be rendered sterile by boiling. The danger which existed in the older forms of the apparatus of liquid chloroform entering the efferent tube and so passing into the face-piece, can be avoided by bringing down the efferent tube as an en-

* I am indebted to Mr. Carter Braine for the woodcut.

sheathing tube over the afferent tube. This will prevent chloroform entering the tubes, even if the bottle is inverted or laid upon its side. There must be at least an inch interval between the surface of the chloroform and the opening of the efferent tube, to avoid the possibility of fluid being forced or syphoned along the efferent tube. The bottle shown in the figure, although graduated for two ounces, should never contain more than one ounce, otherwise the requisite interval between the chloroform and the ensheathing tube is not maintained.

The bottle figured above is one devised by Mr. Carter Braine to obviate the danger of liquid chloroform entering the efferent tube (fig. 64).

There is also a danger if the india-rubber tubing from the bellows, and that to the face-piece, the afferent and efferent tubes respectively, are attached to the wrong tubes on the bottle, that the chloroform may be pumped out of the bottle along the efferent tube to the face-piece. This is more perilous when a mouth or nasal tube is in use. The ingress and egress tubes should be carefully marked distinctively to avoid this mistake. Several deaths have resulted during the use of the older form of apparatus from chloroform being injected into the patient's larynx through the nasal tube. This nasal tube—a flexible tube like a catheter—may be replaced by a metal mouth tube shown in fig. 65, C. *The apparatus should always be tested before use to ensure the proper arrangement of the tubes.*

When chloroform is administered for operations about the mouth or nose, *e.g.*, removal of an upper jaw, the tongue, etc., the anæsthesia, having been obtained by chloroform, is best maintained by fitting the efferent tube of a Junker's inhaler (*i.e.*, the tube not connected with the bellows) over a catheter, and, either passing the catheter through the nostril so that the end hangs down behind the soft palate and permits the vapour to enter the larynx, or else holding the catheter in the mouth. When a preliminary tracheotomy has to be performed and a Trendelenburg's or Hahn's tube is used, the catheter may be held over the external opening of the tube and chloroform vapour so allowed to enter the trachea. The alternative plan of using Crile's tubes is described above.

Another plan is to connect the tube with the gag (Hewitt) and pump the vapour through this tube into the mouth.

Junker's inhaler has been modified by Messrs. Krohne and Sesemann, the original makers (fig. 65). The bottle and tube remain the same, but the face-piece is replaced by a Skinner's mask (see fig. 66) so constructed that the chloroform vapour escapes by a series of holes in the midrib of the frame as in the author's face-piece. The frame is covered by a removable flannel cap. By this contrivance the face-piece is pervaded with vapour instead of a puff of chloroform being intermittently propelled against the face. The advantages

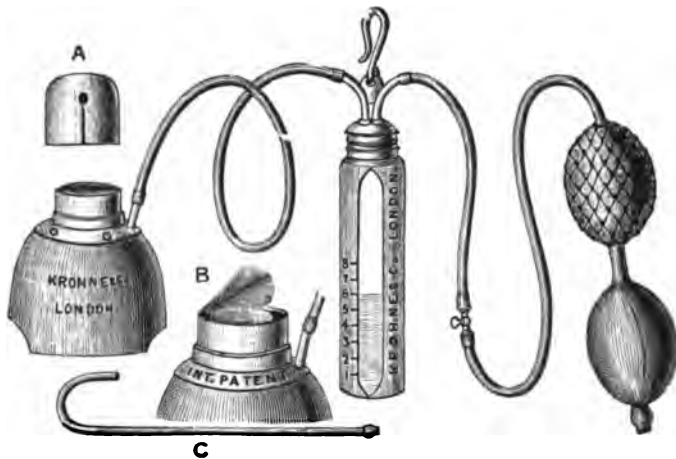


FIG. 65.—Krohne and Sesemann's feather respiration register.

of the flannel cap are (i) its permitting free breathing through its substance, (ii) the patient obtains a free air supply, and further, the administrator can, by placing his hand over the mask, feel whether or not a sufficient blast of air is being expired. It is cleanly, as it can be removed easily and washed.

The feather seen in fig. 65 at B is intended as a guide to the administrator, its movements being a register of the expirations and inspirations of the patient. I think it is not wise to trust to any mechanical test of respiration, however ingenious; I therefore prefer to use either the glass mask or flannel cap. Mr. Krohne has further elaborated the

apparatus so as to permit great dilution of the vapour. Thus with the most recent pattern of the inhaler m^1 can be given and the dose gradually increased. This is effected in the following way. The afferent or air tube, instead of being provided with one compression and one resistance ball as in Richardson's bellows, has three india-rubber balls of different sizes placed at the hand end of the tube. These are made of such capacity that known quantities of air are propelled into the chloroform bottle, according as the large, medium, or small ball is squeezed in the hand. This contrivance is of course only approximately accurate. The actual amount of chloroform taken up by the air which traverses the chloroform

bottle will be influenced by the depth of the chloroform in the bottle, the rate and vigour of compression, and the temperature of the room and of the bottle containing the chloroform. It is increased by shaking the bottle and by splashing the chloroform.

The assumption that for every squeeze of one or other of the pressure balls one minim or less of chloroform is volatilised is probably inaccurate when the method is employed in surgery, although

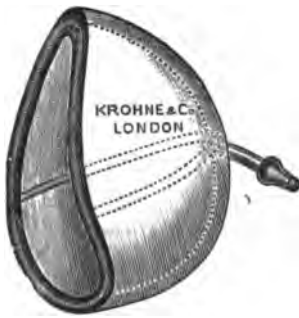


FIG. 66.
Flannel cap for use with Krohne's
Junker inhaler.

it may be approximately true under the controlled conditions of a laboratory. Both Waller and Chapman have proved that as strong a vapour as 6 per cent. may arise when Junker's inhaler is employed.

METHODS WHEN A DOSIMETRIC APPARATUS IS NOT USED.

Many persons prefer to rely upon simpler methods in giving chloroform. The obvious disadvantage of such plans is that even the most expert cannot tell when using them what percentage of chloroform the patient is taking, and must rely solely upon the effects of the anæsthetic on the patient as observed by him. Thus, although the expert chloroformist may employ such a method without grave risk, one

less experienced is liable to give too much or too little of the anæsthetic, being at times either unobservant, or unable to understand the meaning of such changes in the patient's condition as he may notice.

The methods usually employed may be described briefly as the "Scotch," the Hyderabad (which is a convenient adaptation of the first-named and especially useful in hot climates), and the plan of dropping chloroform from the drop bottle upon a mask, or improvised face-piece.

The Scotch method was described by Simpson in the following words:—

"When used for surgical purposes, perhaps it will be most easily given upon a handkerchief, gathered up into a cuplike form in the hand of the exhibitor, and the open end of the cup placed over the nose and mouth of the patient. For the first inspiration or two, it should be held at the distance of half an inch or so from the face, and then more and more closely applied to it. To ensure a rapid and perfect anæsthetic effect—more especially when the operation is to be severe—one or two teaspoonfuls of the chloroform should be at once placed upon the hollow of the handkerchief and immediately held to the face of the patient. Generally a snoring sleep speedily supervenes; and when it does so, it is a perfect test of the superinduction of complete insensibility. But a patient may be quite anæsthetic without this symptom supervening." *

The late lord Lister thus described the Scotch method:—A common towel is arranged so as to form a square of six folds, and enough chloroform is poured upon it to wet an area the size of a hand's palm, the precise quantity poured on not being a matter of any consequence. The patient is instructed to close his eyes to protect them from the irritating vapour, and the towel is then held as near to the face as can be borne without inconvenience. More chloroform is added from time to time as occasion requires. Lord Lister suggests the following simple way of devising a chloroform mask:—The corner of the towel pursed up systematically into a concave mask to cover the mouth and nose, by pinching it together at such a distance from the corner that, when the pinched-up

* Simpson's "Anæsthesia," p. 159.

part is held over the root of the nose, the corner extends freely to the point of the chin. "The cap formed in this manner being so arranged upon the face, chloroform is gradually dropped upon it till the greater part of it is soaked, the edges being left dry to avoid irritation of the skin by the liquid, and the moist condition is maintained by frequent dropping on the convex surface until the requisite physiological effects are produced."

The method in which a drop bottle is employed requires either the use of an extemporised inhaler, such as that suggested by Lord Lister, or of a mask. Those described below are the best known.

Masks.—The Skinner's mask figured below (fig. 67) is the most usual form. It consists of a wire frame on which

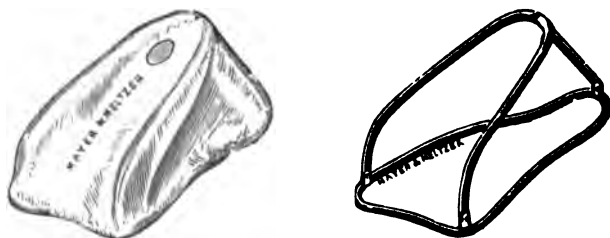


FIG. 67.—Skinner's frame for chloroform.

is stretched a *single* layer of flannel, domett, or lint. The chloroform is allowed to fall *guttatim* upon the upper surface.

An excellent form of mask is due to Schimmelbusch. It consists of a metal frame on which are fixed two bent semi-circles at right angles. These fit into the frame when not in use, but when used, open out and form a cup over which is stretched a *single* layer of lint kept in position by the hinged rim, which is attached to the frame. It is used with a drop bottle, or chloroform sprinkled over it (fig. 68).

The Hyderabad cone, as devised by Dr. Lawrie (fig. 69), is essentially a calico mask with some cotton wool in its apex and its sides strengthened by thin strips of wood. Into this two drachms of chloroform are poured, and the mask held a little way from the face until the patient is accustomed to the vapour, and his nervousness has passed away. The mask is then brought gradually nearer to the face. Chloroform is

poured on from time to time as required. To do this the cone is inverted and a drachm of chloroform poured into it. The breathing must be most carefully watched, and if any interference with its rhythm occurs the mask must be at once removed, and when the breathing resumes its natural character the cone is again gradually brought into position. Care must be taken that chloroform is not dropped on the skin of the face, or into the eyes.

The administration.—Whatever method is employed the same result is aimed at, and the rules guiding the administrator, as well as the phenomena shown by the patient during inhalation, are so essentially similar that it is proposed to

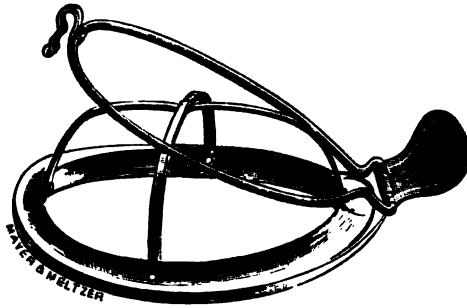


FIG. 68.—The Schimmelbusch mask.

consider the course of narcosis under chloroform in general, noting later such special points as may need further elucidation in relation to special methods.

The patient should be carefully prepared, for this is perhaps even more important in the case of chloroform than in that of any other anæsthetic. Vomiting nearly always occurs during the induction of anæsthesia when the stomach contains food, and when the bowels have not been properly regulated. Associated with it are lowering of the blood pressure and increased liability to syncope.

Posture.—The patient must be placed recumbent, with all his clothing absolutely loose. The sitting posture was believed by Snow to be a safe one for chloroform narcosis, but in view of our present knowledge it seems highly important that, even for short operations, the chloroformist should insist upon the recumbent posture. An attempt has been made recently to

re-introduce the sitting posture during chloroform narcosis, but its advocates appear to ignore the well-authenticated reasons which negative such a position. It is perfectly true that *after induction* when the patient's circulation has adjusted itself to the changed conditions, and if the narcosis is not profound, a patient can without serious danger be propped up to a height convenient to the surgeon. Even this procedure is not entirely devoid of risk, and the wiser plan is to induce anæsthesia with ether and rely upon chloroform for keeping it up during the operation. Whenever the exigencies of the operation permit, the head should be placed at a lower level than the abdomen. In the first degree of narcosis the head

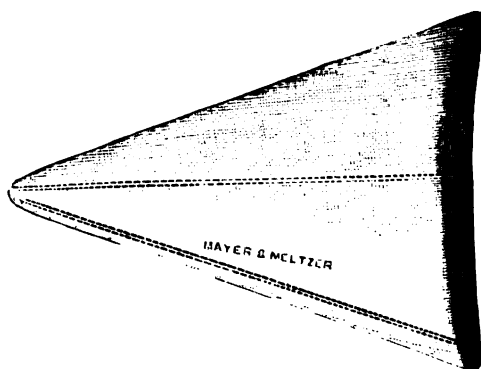


FIG. 69—Hyderabad cone.

may be allowed to be somewhat higher, as most persons, more especially the stout, feel uncomfortable and may find breathing difficult if the head is very low. The pillows must be so arranged that the head is slightly extended upon the trunk, never flexed with the chin resting upon the breast. Over-extension tends to cause dropping of the chin with falling back of the tongue, while extreme flexion interferes with natural respiration. When the second degree of narcosis is reached, the head should be lowered and the face turned to the side.

The inhalation.—If a preliminary hypodermic injection is to be given it is introduced $1\frac{1}{2}$ hours before the chloroform is inhaled, but in the following account the assumption is made

that no such course has been adopted. The patient, having been reassured, is asked to breathe naturally and not to hold his breath. A moment or two spent in demonstrating how this is done is generally time saved. In whatever manner the chloroform is given, whether from an inhaler, or from a Skinner's or other mask associated with use of a drop bottle, as by the open method, the greatest care must be taken to give a very dilute vapour at the commencement of the administration. The mask, or lint, should never be placed close to the face immediately, but at a distance of a few inches, being gradually approximated. There must always be a free flow of air entering round the frame, and expiration must be unhampered when the open method is in use. As chloroform may drop on the skin, the chin, cheeks and nose, should be smeared with vaseline and the eyes protected by a piece of lint. Coughing, holding the breath, struggling, nearly always arise from too strong a vapour being presented to the patient. Soon the strength of the vapour can be increased. The patient becomes restless, talks nonsense, tries to move. Struggling may be very violent especially in the case of muscular, of athletic, and also of alcoholic persons. It is always a dangerous complication as the muscles become spasmodically contracted, interfering with breathing and imposing a great strain upon the heart.

The chloroform must be withheld until breathing is normal again and the patient must be prevented from hurting himself and from getting off the table. Care and tact in doing this are essential as violence in restraining the patient provokes fresh violence on his part. The pupils now gradually dilate and the eyeballs roll from side to side. As the stage of excitement becomes more pronounced the breathing must be carefully watched. The amount of excitement shown varies, not only with the individual patient, the strong and muscular evincing most, but also with the method employed. With dilute vapours, for example, when the Vernon Harcourt regulator is used, the excitement stage is usually very brief and ill-defined or absent. Even when no previously known obstruction exists, such as nasal stenosis, buccal growths, enlarged tonsils, pharyngeal or laryngeal tumours, interference with respiration during inhalation may occur from spasm of the

masseters, closure of the lips, laryngeal spasm (see Complications), epistaxis, vomiting, falling back of the tongue, or fixation of the chest by muscular spasm. Such interference with respiration, as it introduces some degree of asphyxia into the case, is pregnant with danger and must at once be met by removing the mask if a non-dosimetric method is in use. If the obstruction is in the upper air passages, opening the mouth with a gag or separation of the lips with the finger will usually enable the patient to take one or two inspirations, which will probably tide him over the period in which muscular spasm exists. The mouth and upper pharynx must, of course, be examined with the finger, if there is any reason to expect the presence of foreign bodies in the buccal cavity. In opening the mouth care must be taken, if spasm exists, not to break or displace loose teeth, especially when using Heister's mouth opener. As a rule the finger inserted behind the teeth will force open the jaws sufficiently for the insertion of a wedge or gag. In the stage of excitement the chloroform should be pushed, provided respiration is unimpeded and regular, but if the respiration is impaired, the anæsthetic must be withheld altogether until breathing is again normal. Excitement passing off, rigidity of the muscles may persist for a time, even though the loss of lid reflex and fixation of the eyeball with a contracted pupil evidence the passage into the true anæsthetic condition (third degree of narcosis). This muscular rigidity eventually disappears; some muscles, however, *e.g.*, the recti abdominis, often remain rigid for a considerable time, especially if any excessive limitation of air has been allowed during the induction.

The breathing is now regular, sometimes a soft snoring is heard, but no noisy stertor should exist. Its presence is evidence of obstructed breathing and its cause must be sought and removed. The administrator should notice whether expiration is fully performed and whether there is any duskiess about the face or ears. **Cyanosis, however slight, is to be avoided**; it is caused by excessive quantities of chloroform and failing respiration. As soon as the patient is anæsthetic (third degree) the amount of chloroform must be lessened and only so much be given as is required to maintain

anæsthesia. Young children often appear to have passed into this degree of narcosis when merely asleep, but if the progress of the case has been carefully observed, no mistake need be made. A watch kept on the respiration, the colour of the patient, and the condition of the **pupils** and **eyeballs** will enable the administrator to keep his patient anæsthetic, without deepening the degree of narcosis.* During the induction the eyeballs move; the pupils react to light and gradually dilate. During the stage of excitement the dilatation becomes more marked. In the degree of true anæsthesia the eyeballs are fixed, and the pupils gradually contract, but remain sensitive to light; the lid reflex disappears. In the fourth degree the eyeballs are rigidly fixed, slightly rotated upwards, the pupils dilate and are insensitive to light. This dilatation reaches its acme as death occurs in the fifth degree of narcosis.

The early signs of **returning consciousness** are, moving eyeballs with dilating pupils, return of the lid reflex, active reflex to light, and, if vomiting is about to occur, the patient swallows, grows pale, and his respiration becomes weak. On the other hand, the signs of **deepening narcosis** are duskiess or pallor, dilating pupils with fixed eyeballs, complete loss of the "light" reflex, flaccidity of the muscles, weakened respiration, and soft feeble, almost imperceptible, pulse.

The pulse, although a valuable sign of the *general condition* of the patient, is no guide by itself of the degree of narcosis. In cases in which much shock and hæmorrhage are present, the narcosis will rapidly deepen, even although no increased supply of chloroform is being given. This arises from the fact that the nervous system when drained of blood is more readily narcotised.

* Mr. Rutherford of Cambridge (*Brit. Med. Jour.*, June 21, 1913) contends that the lacrimal gland offers reliable information as to the depth of narcosis. As he mentions four "stages," it is difficult to be sure of the periods of narcosis to which he refers. In the "preliminary stage" the effect varies with the local irritation; in the "excitement stage" secretion is active, tears form a pool at the inner canthus; during the "stage of surgical anæsthesia" the lacrimal glands cease to secrete usually "before the complete abolition of corneal [*sic*] reflex." In the "stage of over-dosage" no lacrimation occurs. It is doubtful I think whether these conclusions have as universal an application as Mr. Rutherford affirms. His observations are interesting.

The degree of narcosis must be deepened or the reverse, according to the strength of the patient and the nature of the operation. When the patient is not made completely anæsthetic or the degree of narcosis is inadequate to the nature of the operation so that the patient rapidly becomes no longer anæsthetic owing to painful sensory stimulation, conditions arise which are dangerous. When a patient is very lightly under chloroform there is always a risk lest the administrator should keep up a see-saw between excessively slight and unduly deep narcosis. Irregular breathing, and a tendency to strain, cough, or vomit commonly appear under these circumstances, and the anæsthetist is tempted to put an end to such inconveniences by suddenly giving a greatly increased strength of chloroform vapour. This, under such circumstances, is tolerably certain to lead to over-dosage and danger. A full and continuous anæsthesia should be aimed at, and to effect this it must be borne in mind that the intake of the anæsthetic should be equal to the amount exhaled by the patient. During the early part of the induction more chloroform enters than is expelled by expiration. In true anæsthesia about the same amount enters as is given off, and as soon as the percentage strength is lessened the quantity expired will exceed that inspired. This should occur steadily as the anæsthesia is maintained, since very much less chloroform, or rather a much lower percentage of chloroform vapour, is needed to prolong anæsthesia than is necessary to establish it. This is true provided respiration is not interfered with; if obstruction occurs, less chloroform may leave the lungs and remain active in the cells of the tissues. While undue haste is always dangerous, excessive slowness in the induction of chloroform narcosis is also undesirable, and there is a proneness to sickness, and with it a fall of blood pressure which often induce extreme depression, or syncope. The time occupied in the induction varies considerably. The peculiarities of the patient, and the method may delay or hasten the onset of anæsthesia. Five to ten or even fifteen minutes may be required. Besides the loss of conjunctival reflex, it is wise to ensure regular easy breathing, a good colour, and a relaxation of the muscles before the operation is commenced. In abdominal operations this is extremely

important and an extra few minutes are well spent in obtaining such a result. If the induction is hurried and anæsthesia barely obtained, the commencement of the operation will cause the patient to pass back rapidly into lighter narcosis, the breath will be held, and the respiration become irregular. It will be extremely difficult if this has occurred to obtain subsequently a satisfactory anæsthesia throughout the operation.

It is very important to appreciate the fact that light narcosis, *i.e.*, below the third degree, is undesirable, if not dangerous, at the period at which an operation is commenced; yet when a patient has once been taken through the third degree and is truly anæsthetic, he may safely and satisfactorily pass back into the second degree during the subsequent conduct of the operation.

RECOVERY FROM THE EFFECTS OF CHLOROFORM.

Of persons who pass easily under chloroform, and who have taken only a small quantity, the recovery is marked by few noticeable symptoms. They awake as from sleep, are sometimes sick, or feel slight nausea, rarely complain of the persistence of the taste or smell of the vapour, and are prone to sleep. Snow states that persons become conscious in ten minutes after ceasing to inhale. When chloroform is carefully given by a dosimetric system it is quite usual for a patient to resume consciousness within a few minutes of being returned to bed. They then usually go to sleep again and may sleep for an hour or so. If morphine has been given before the anæsthetic the unconsciousness persists for a longer time, it may be four or six hours. Old people are slowest to awaken. To all patients, and especially to the weakly, and to those who have gone through a severe operation where much blood loss or shock was present, owing to the fall of blood pressure and the ischæmia of the cerebral circulation, syncope is a grave danger. Sudden sitting up, as in the act of vomiting, even the lifting the patient, may cause faintness. Numerous deaths have been reported after chloroform inhalation owing to the patient having been put back to bed and left unwatched. The patient in these cases has been suffocated either from

malposition of the head, or through vomiting having taken place and the aspiration of the vomitus into the air passages.

Difficulties arising during the induction of chloroform anæsthesia.—Nervous persons and young children commonly **hold their breath**, or breathe so softly that they inhale insufficient vapour to establish anæsthesia within a reasonable time. This is usually the result of commencing with too strong a vapour. If the anæsthetic is withheld for a few respirations, the patient will resume his usual breathing and the chloroform can be given again, only more gradually. Breath-holding in the semi-unconscious state arises reflexly and from the same cause and may be remedied in a like manner. **Screaming** in children needs care lest the deep breaths take in chloroform too rapidly. It should be given very slowly until the child has stopped its cries.

I have met, however, with powerful men who while in the second degree held their breath and struggled, repeating the process at each attempt to give them chloroform. This condition is obviously dangerous, as any attempt to push the anæsthetic leads to disaster. It can be overcome by changing to ether, giving it either by an inhaler or an open mask freely for a few inspirations. All air is excluded, the patient is held, and a few compressions of the thorax are made with one hand. As soon as respiration is well started, chloroform can be substituted for the ether. **Struggling**, although frequently due to too strong a vapour, especially quite at the beginning of the administration, may arise from other causes not associated with over-dosage. In the highly nervous, the neurotic, and especially in the alcoholic, the condition is common and pronounced. Unless the administration is being conducted by an accurate apparatus, which enables the chloroformist to lessen the percentage to one per cent. of vapour, the chloroform must be at once withdrawn until the breathing has resumed a regular rhythm. It is then to be given again, but more sparingly. **Breathing** may grow more and more **shallow**: **pallor** may appear due to interference with the circulation. This alarming association of symptoms is not infrequently seen in children and feeble subjects. Its cause may be some slight interference with the breathing, such as sucking back of the tongue, falling of the jaw, mucus

collected about the laryngeal aperture, or epistaxis, and the cause of this condition must be carefully sought for, and when discovered remedied.

The dangers of struggling when chloroform is being inhaled are often due to fixation of the muscles of respiration and irregular breathing. The patient holds his breath, fixes his diaphragm and chest and so impedes respiration and circulation. He then suddenly takes deep breaths which, if the chloroform mask has not been removed, will flood his lungs with a strong vapour and an **over-dose** is taken. It is the concentration of this vapour, not its actual amount, which is deleterious. **Semi-asphyxia** provokes further struggling and this leads to the entrance of more of the high percentage vapour into the lungs until the nerve centres, which are rendered more vulnerable by being deprived of oxygenated blood, are poisoned beyond recovery. Hence the absolute rule that **any interference with respiration calls for withholding chloroform** unless it is being given by a dosimetric inhaler and its concentration is not above one per cent.

The lips are often tightly closed over the teeth clenched by tonic contraction of the jaw muscles. If the tongue is caught between the teeth it will be badly bitten. To prevent this some anæsthetists place a dental prop between the teeth before starting the inhalation. Weakening of respiration and pallor in asthenic and especially in anæmic patients are usually due to a feeble state of the heart. If the head is placed at a lower level than the trunk, the symptoms of faintness will disappear and the induction will pursue a normal course. Retching and even vomiting may occur as a patient **begins** to inhale. When it is known that there is no food in the stomach, and that no condition exists which might lead to regurgitation of intestinal contents—as in cases of obstruction—increasing the supply of chloroform and pushing forward the lower jaw rhythmically will usually succeed in preventing vomiting. Nervous persons are liable to this inclination to vomit and it is often the accompaniment of faintness. However, if food or intestinal contents are vomited, in spite of all precautions, the chloroform should be withdrawn, the patient's head kept low and turned to one side. Care must be taken by swabbing out the mouth to prevent aspiration of the vomit into the air

passages. It is best before recommencing the chloroform to request the surgeon to have the stomach washed out. This is seldom necessary, however, in the case of young children. When once anæsthetised, the patient should not be moved or shaken, nor must he be exposed to draughts or any conditions which will chill his body.

Irregular breathing is a symptom to be carefully noted and corrected. It may arise from too rapid an induction by too strong a vapour, in which case the air limitation must be lessened and a weaker vapour given; or from too shallow a type of breathing, and a "see-saw" method of giving the anæsthetic, such as by pouring a drachm of chloroform on the mask and letting it evaporate. Systematic dropping will correct this. Irregular breathing in light narcosis often heralds in faintness or vomiting.

The operation should never be commenced until the respirations are regular and sufficient and the ocular signs indicate that the patient is in the third degree of narcosis.

Epileptics commonly have a fit during the induction of anæsthesia, and this alters the respiration materially. Provided the patient's tongue is protected from being bitten, the fit is no indication for withholding chloroform except at the time at which the breath is held.

Young children are very prone to **irregular sighing breathing**, especially if they have cried and struggled in going off. The breaths are grouped, getting gradually weaker, then comes a pause followed by a long-drawn deep sighing breath, and this may very readily lead to over-dosage. It is best to lower the head and stimulate breathing by rubbing the lips, lifting the jaw, or by giving a little ether.

An extremely important point to bear in mind is that, although the loss of conjunctival reflex is regarded as the criterion of true anæsthesia, yet many operations may require a more profound narcosis than exists at the time this reflex disappears. Undoubtedly deepening narcosis in all cases is fraught with danger, and the administrator who has to bring this about must be sensible of the risks and watch the signs of deepening narcosis with the utmost care. The relaxation of the recti muscles in strong athletic adults, and the slow shallow breathing which are commonly considered necessary

for the proper performance of abdominal operations, can only be obtained by increasing the dose of chloroform until the medullary centres are profoundly narcotised. At this stage any interference with respiration, or the occurrence of hæmorrhage, may lead to enfeeblement of or even to cessation of respiration. The blood pressure becomes lowered when the patient is profoundly narcotised, and it is liable to fall still lower, thus lessening the flow of blood through the coronary circulation.

Persons of different **physique** require different amounts of chloroform, and the requirements of operations also call for a like variety of treatment. It will be found that these variations in dosage are especially needed at the period of induction, but are called for also in the later phases of the administration. Thus the feeble and those who are profoundly shocked will need very little anæsthetic to maintain anæsthesia; the vigorous and alcoholic will require a large amount to keep them relaxed and without movement. Since the severity of the after effects is directly due to the amount of the anæsthetic which the organism has to eliminate, it is necessary to limit the quantity given as much as the exigencies of the operation and those of the individual will permit.

As to the incidence of **danger**, it may be fairly stated that the strong and athletic are, if anything, more liable to accident than the feeble. No age or temperament is free from possible peril, nor can it be accepted as truth that a person who has many times taken chloroform with impunity therefore enjoys an immunity from its risks. Chloroform, like any other drug, produces effects corresponding to dosage, and there is little doubt that for most persons the dose is determined by their body weight and physique. It is possible, nay even probable, that the resistance evinced by some patients is peculiar to themselves. Just as minute doses of potassium iodide, or other drugs, will cause great inconvenience to certain people, so even small amounts of chloroform will produce much greater physiological effects upon some persons than upon others. It is this which renders it necessary to commence the administration of chloroform with caution, and only augment the dose when

it has been ascertained how the patient reacts under its influence. Nor can it be too strongly urged that only by constant observation of the phenomena and a right interpretation of their significance will safety and success be ensured. The guides are first and foremost **respiration**, which must be studied, not only by watching the thoracic movements, but also by noting the force of expiration. This is best done by placing the hand from time to time over the patient's mouth. The colour of the face, lips, and ears will give a fair indication of the state of the blood; while a finger placed on the pulse occasionally will gauge the blood pressure; and the ocular phenomena indicate the depth of narcosis. In the early degrees the conjunctival reflex is brisk, the pupils are moderately dilated, and the eyeballs move more or less slowly. In the third degree—the stage of true anæsthesia—the conjunctival reflex is abolished, the eyeballs cease to move, and the pupils contract and may be reduced to a pin's point. Deeper narcosis, when the patient is passing into the fourth degrees and the medullary centres are becoming over-dosed, is shown by gradual failure of respiration, most marked by the feebleness of expiration, by dilatation of the pupils and loss of the light reflex. Ocular phenomena are of less value as a guide in the case of children. It should be remembered that the conjunctival reflex disappears before the corneal reflex, and that the latter therefore signifies a profounder state of narcosis and one which is very near the zone of danger. As will be evident from a study of this and the following sections, many if not most of the difficulties and complications connected with chloroform inhalation arise during the period of induction. The largest number of fatalities also take place at this time. It is then obvious that we should consider in this place whether there are any special methods the adoption of which will obviate such dangers, and further whether in particular types of persons the pursuing of measures may not remove the dangers, and lessen the difficulties especially associated with such types.

What is the position of chloroform as regards its safety?

The formidable list of deaths and dangers which must be present in the mind of the student of anæsthetics is apt to produce an undue feeling of timidity in handling this

anæsthetic. There is no doubt that chloroform is dangerous when given by a tyro and by a method which leaves the strength of the vapour employed rather to chance than to knowledge. When once the lesson is learned that copious dilution of its vapour removes practically all its dangers and that this is best done by some scientific method ensuring definite percentages so that a maximum strength at or below 2 per cent. is ensured, the anæsthetist soon recognises how safe chloroform administration can be made. As Waller has pointed out, the essential training of a chloroformist consists in his making himself master of the phenomena associated with any given percentage strength of vapour. This accomplished, he will rarely allow his patient to get a vapour strength above 2 per cent. whatever method he pursues, and if he does so it will be of set purpose and with a keen appreciation of the fact that he is encroaching upon the danger zone. Such a training is best obtained by the use of some dosimetric apparatus such as the Vernon Harcourt inhaler, as this will enable the learner to study the wide range of difference which exists among individuals as regards the way they react towards this anæsthetic. Thus, if a 2 per cent. is a safe maximum for an ordinary person, the patient whose respiration is hampered will require less. While the maximum is needed for induction, persistence in its use when the operation has been in progress for some time will lead to an excessive depth of narcosis. The danger of open methods is that they tend to establish stereotyped systems of dosage, since it is more difficult to lessen the amount given, as they also tend to hasty and ill-judged increase of dosage at moments of stress when the surgeon calls for a deeper narcosis. Although the experienced man may be proof against such imperfections in the methods, the beginner is not, and can only become so when he has learned to estimate the exact effects of definite dosage with chloroform.

MIXED METHODS OF GIVING CHLOROFORM.

1. Antecedent employment of alkaloids.
2. Antecedent use of other anæsthetics, *e.g.* nitrous oxide followed by ether.

3. Ethyl chloride followed by ether, followed by chloroform.
4. Combinations of alcohol and chloroform.
5. Combinations of ether and chloroform.
6. Methods combining two or more of these methods and the routine employment of oxygen.

All these **sequences** are discussed in a later chapter, so that it only remains to point out that when alkaloids are employed the induction is more tranquil, and so is probably more safe ; less of the general anæsthetic is required—thus the after effects are diminished.

The object of employing such sequences as nitrous oxide—ether—chloroform, ethyl chloride—ether—chloroform, is to shorten the induction period ; such sequences also possess the advantage of presenting to the patient a safer anæsthetic at the time when struggling—the main danger of chloroform when given by open methods—is most liable to occur.

When a patient has had a spinal anæsthesia established and its effect has passed off before the operation has been completed, the anæsthetist may be called upon to administer chloroform. In doing this he should bear in mind that the patient has probably taken food, or in some cases alcohol, shortly before the injection was made and so will be prone to vomit while inhaling chloroform.

THE USE OF CHLOROFORM IN THE CASE OF SPECIAL TYPES OF PATIENTS.

1. Children and the aged.
2. Extreme asthenia.
3. Athletic persons.
4. Alcoholic persons and those addicted to drugs.
5. Persons suffering from asphyxial conditions.
6. General diseases of respiration, circulation, and the nervous system.
7. Toxæmia.
8. Pyrexia.

1. Chloroform in the extremes of life. **Infants and young children.** The dictum that children are less liable to accidents

under this anæsthetic than are adults must be dismissed as untrue. The very young are peculiarly liable to danger during the induction period, and to grave after effects (post-chloroform toxæmia—acidosis), so that especial care is essential in their case to avoid over-dosage. Open methods so commonly employed are especially apt to lead to this, since children are usually terrified, often hold their breath and gasp, their respiration being alternations of breath-holding and violent and deep inspirations, making induction both difficult and dangerous. Further, children often go to sleep under chloroform, and in this state respiration is so shallow that unless the little patient is roused and breathing made deeper, he will take a very long time to be rendered truly anæsthetic. It is often extremely difficult to decide whether a child is asleep or "under," the phenomena are practically the same, so that some pain-giving stimulus must be applied before the operation is commenced. The apparent tolerance of large quantities of chloroform is really illusory, the fact being that owing to poor lung ventilation very little of the chloroform vapour is actually inspired. Dosimetric methods are certainly the best for children, although, owing to the difficulty of obtaining an accurately fitting mask for a small child, such methods are not easily applied. With delicate children it is best to have the head lower than the trunk and, if breath-holding and struggling occur, to replace the chloroform by ether used by a dropping method until the child has become unconscious. The pungent vapour rouses the patient and his struggles induce deep breathing, which is an advantage with the last-named anæsthetic. A few drops of eau de Cologne dropped with the chloroform disguises the smell of the latter, and will often induce the timid child to breathe easily and willingly. No pallor or asphyxial complications should go unrelieved, as serious danger comes rapidly in the case of children. Depression of the head will relieve the one, and hooking forward the mandible with a finger in the mouth will remove the other, especially if the child's chest is compressed with the hand. The chloroform must be withheld while these steps are taken.

Children who have struggled and breathed in an irregular fashion during the induction commonly develop a curious

type of respiration. The breaths are grouped as in Cheyne-Stokes breathing; then follows a deep sobbing inspiration which is succeeded by an apnœic pause. This condition is one of danger and is usually associated with pallor and blueness of the lips. The anæsthetic must be withdrawn and oxygen given while respiration is encouraged by chest compression and rubbing the lips with a soft handkerchief. If chloroform is persisted in at all, it must be given very sparingly and much diluted, but as a rule little if any more anæsthetic will be required for some minutes. Under no circumstances should the inhaler be reapplied until the respiration has become more satisfactory and regular.

Simulating the condition just described as due to over-dose and fall of blood pressure, is one which arises from quite another cause, viz. too light a narcosis. The pallor in this latter state is premonitory of the act of vomiting. It is unwise to attempt to check this in the case of delicate children, since vomiting is always associated with a fall of blood pressure often very considerable. When retching has ceased the anæsthetic should be reapplied, the head being lowered and complete narcosis of the third degree—anæsthesia—established. The effects of cold and of shock and of prolonged fasting tell rapidly upon children, and must be counteracted, or chloroform given in even small quantities will depress these patients to a dangerous degree. Children under chloroform, if lifted at all, must be carried with the utmost care to avoid the head being raised or the body jolted.

2. In the case of extreme **asthenia** the danger of undue fall of blood pressure is to be kept in mind and avoided by keeping the strength of the vapour low. Such patients really require very little of any anæsthetic and cannot take an ordinary strength of vapour without risk. If respiration is poor and the lips are bluish, oxygen should be given very freely.

3 and 4. **Athletics, muscular persons and alcoholics** are peculiarly apt to struggle in the initial stages of the induction period, and later there is usually marked muscular spasm which may seriously prejudice respiration. These conditions are often, if not always, the outcome of some asphyxial state

due to breath-holding, excessive strength of the vapour inhaled or sucking back of the tongue. Any such cause must be sought for and remedied. It is dangerous to attempt to overcome muscular spasm by pushing the anæsthetic; indeed unless the chloroform is being given by a dosimetric method, which is the safest for patients of such types, the anæsthetic should be withdrawn until the complication has passed off.

The **habitual use of hypnotics** renders patients difficult to anæsthetise. They take a large quantity of chloroform and are apt to pass into a drowsy condition in which the respiration is shallow, so that they actually get little of the anæsthetic into their lungs. The knowledge of this fact will provide a clue to the remedy, viz. constant attention to the breathing and stimulation by lip rubbing, jaw traction and so on. When anæsthesia has been once established the amount of chloroform given must be lessened, as such patients remain deeply anæsthetised for a long time after the anæsthetic has been withdrawn.

5. Pre-existing **cyanosis** due to some cause which impedes respiration requires the use of oxygen and high dilution of the chloroform. If the cyanosis depends upon a condition the effects of which may become accentuated under narcosis, this fact must be borne in mind and precautions adopted. The interference with respiration due to lesions of or pressure upon the spinal cord, is best treated by inducing anæsthesia slowly by the use of a Vernon Harcourt regulator and a free supply of oxygen. When full anæsthesia is obtained practically no more anæsthetic will be needed until the close of the operation, when the skin sutures are introduced. The head should be kept rather high in the case of such patients. Respiratory failure is peculiarly liable to occur during operations upon the spinal cord, especially if a deep narcosis has been incautiously allowed to arise. After the initial incision the patient should be in the second degree of narcosis.

6. No general rules can be formulated for these cases since each case must be managed with the view of combating the dominating dangers incident to the particular disease. **Respiratory difficulty** calls for careful attention to posture,

limitation of the strength of the vapour in use, and sedulous avoidance of "crowding on" of the anæsthetic. Oxygen is of great assistance. Perhaps the main fact to be emphasised is that throughout the giving of chloroform to such patients the attention should never be allowed to flag from watching the breathing. The slightest lessening of its amplitude if associated with pallor and returning activity of the conjunctival reflex usually means the narcosis is too light and more anæsthetic is needed. It is, however, necessary to ensure full respiration while this is being done, or the blood pressure will fall and danger ensue. Pulling forward the tongue and pressure on the chest are commonly successful in restoring normal respiration. If, however, respiration grows shallow and irregular, and associated with this are cyanosis, pulselessness with some dilatation of the pupils, the ocular globes being fixed, and there is also loss of the conjunctival reflex, the patient has taken what to him is an over-dose. The anæsthetic must be withdrawn, oxygen given and respiration restored by the usual means. **Circulatory failure** again may be the dominating danger, and if this is recognised the anæsthetist will have the key of the situation, for he will know that a low blood pressure is only consistent with an amount of the anæsthetic which under normal conditions would be inadequate. Posture also in these cases is important so that the nerve centres may not be unduly depleted of blood. **Diseases of the nervous system** become important in the present connexion in so far as the lesions interfere with the due nerve controls of respiration and circulation. Such interference has already been considered. The tremors of **paralysis agitans** disappear under anæsthesia. When **bulbar paresis** exists the utmost care must be taken to maintain the patency of the air passages and strict limitation of chloroform practised. Any asphyxial complication is peculiarly dangerous in these patients. Diseases in which the **quantity** and **quality** of the blood are affected are, I think, especially dangerous, because we possess abundant evidence to show that the tissues of the body are more easily affected and damaged by even small quantities of chloroform and are liable to suffer from oxygen deprivation, when the blood supply is inadequate or its quality is poor.

7. Germane to these considerations is the question of **toxæmias**, and with this we may include that curious congeries of symptoms called **lymphatism** or **status lymphaticus**. So far as we know, those who at death reveal the lesions of hyperplasia of the lymphatic structures, a depraved blood condition and often imperfectly developed heart and blood vessels, show no well-marked clinical signs of their state which differentiate them from delicate children and adolescents. Whether they, like cretins and others, are in fact poisoned by an auto-toxæmia cannot be discussed in this place. It will be sufficient to say that in all toxæmic states such as cholæmia, uræmia, cancer, diabetes, septicæmia, and lymphatism the resistance of the tissues against chloroform is lowered. To put it another way, if in normal persons a given quantity and vapour strength of chloroform are safe and will produce anæsthesia without causing toxic symptoms, that amount will in the case of all persons who suffer from toxæmia prove dangerous and even lethal. The problem, which must be solved for each individual patient, is to discover, by careful adjustment of the anæsthetic, how far it is safe to push it. It will be found that very little is really required to induce unconsciousness and still less to maintain it.

8. The condition of **pyrexia** again falls almost into the category of cases classed under toxæmia, and its treatment from the point of view of the anæsthetist is that already enunciated. It may, however, be added that the heart factor is an important one in pyrexia, and its dangers are in most cases connected with cardiac failure.

Complications arising during the administration of chloroform and their treatment :—

General minor complications.—A word may be said about posture. The arms must be placed so that there is no possibility of pressure being exerted upon nerve-trunks, as this may cause peripheral palsy. The face and eyes must be guarded against chloroform dropping upon the skin or conjunctiva. Vaseline over the point of the chin, the nose and the cheeks, and castor-oil dropped in the eyes will prevent this danger. When dropping the anæsthetic from a bottle

care is necessary that the last drop does not fall outside the mask and on to the face or neck. If the patient is a child its heels should be held, or be put on a pillow, as an infant is liable to bruise them if it kicks. High-bridged noses of the "Roman" type should be protected or the pressure of a mask or face-piece will leave them sore and painful for days. Urination and defecation may occur during the induction and need proper attention. When the lithotomy position is used the thighs must not be forced back too much on the abdomen, as in stout persons respiration may be interfered with in such a position, while neuritis and palsy or even rupture of the popliteal artery have been caused by careless fitting of the Clover's crutch. The strap of the crutch must be placed over one shoulder and under the opposite one, and the face turned to the latter side.

INTERFERENCE WITH RESPIRATION.

This may arise from **MECHANICAL CAUSES**, or result from the direct action of chloroform upon the **RESPIRATORY MECHANISM** (over-dose).

The symptoms evoked will depend upon the extent to which the patient's breathing has become hampered, and the treatment will vary according to the cause.

1. **Mechanical.**—The falling together of the aryæno-epiglottidean folds occludes the larynx, and interferes with inspiration. It is an extremely common accident, and if not observed and remedied may become very serious. The patient's breathing becomes irregular and harshly stertorous, the chest movements are not stopped but their amplitude is lessened, the face grows dusky, and this is seen especially in the ears and lips. Respiration then ceases, and the patient's face becomes black. Inflammatory or other swellings pressing upon the trachea or lessening the patency of the upper air passages, binding down of the tongue or neck by old scar tissue, engorgement of the tongue, tonsils and adjacent structures may interfere with respiration. These conditions, however, do not always give rise to symptoms until the patient is partly under chloroform or until struggling or breath-holding has produced some asphyxial

condition. When this last occurs the symptoms rapidly develop and respiration becomes hampered.

The tongue may fall back and so occlude the laryngeal opening. When the patient is deeply under the anæsthetic the lower jaw and with it the hyoid bone drops, and the tongue is carried back so as to close the larynx. The air is thus prevented from entering the lungs, as every inspiratory effort only sucks the epiglottis back. It thus acts as a valve permitting some expiration, but no inlet of air. The movements of the chest still persist, although practically no air is entering. As asphyxia is developed the respiratory movements become irregular, and finally cease. Usually, but not always, snoring stertor is present under these circumstances. The signs of asphyxia are soon seen, the face becoming dusky, then blue, and finally a mottled black, the pulse weakens, and, unless promptly relieved, the patient dies.

Mucus, or blood clot, or other fluid such as vomitus, may sometimes collect over the upper opening of the larynx, and in persons whose respiratory efforts are not vigorous may cause suffocation. Insufficient air exchange leads to signs of asphyxia more or less pronounced, the most striking of which is the progressive duskiness of the patient's face. In this case the pharynx should be sponged out and the chin jerked up, a manœuvre often sufficient to dislodge the obstruction and restore normal respiration.

The posture requisite in various operations hampers breathing, and if the patient is profoundly under chloroform it often leads to interference with breathing. Such positions are: the extreme "lithotomy," when the thighs are flexed strongly upon the abdomen and the buttocks supported on a sandbag; extreme Trendelenburg, when the intestines and abdominal contents press upon the diaphragm, limiting its excursion—this is made worse if the arms have been brought up and fastened above the head, thus in part fixing the thorax; the "semi-prone" and worse, the "prone," adopted in some kidney and rectal operations; the lateral decubitus in cases where an empyema or extensive pleural effusion is present. It is absolutely essential, if chloroform is used at all for these patients, that the anæsthetic should be given lightly, and after full anæsthesia has been obtained the patient should

be allowed to pass back into the second degree with a fairly brisk conjunctival reflex. Any progressive cyanosis is a definite warning that the posture must be altered and the patient's breathing restored to its normal amplitude.

Entrance of foreign bodies into the larynx or trachea.—

Teeth, natural or artificial, portions of bone, blood clot, pus, vomit, nasal polypi, masses of new growth, gags, sponges, gauze mops, may drop back and enter the air passages, or, in the case of solids, may become jammed in the œsophagus, and so provoke asphyxia by mechanical pressure upon the larynx. Small or soft substances which enter the larynx may set up spasm and so prevent passage of air, or they may pass into the trachea, or bronchi, and produce urgent dyspnœa and suffocation. So long as the coughing reflex persists foreign bodies will not, as a rule, pass the vocal cords, but in deep narcosis this safeguard no longer exists. It is, therefore, better to employ light narcosis in operations upon the buccal cavity and upper air passages in order to avoid the danger of suffocation through foreign substances or liquids entering the lungs.

Treatment.—The falling together of the arytxeno-epiglottidean folds and falling back of the tongue are less liable to occur if the head is placed on the side, so that the weight of the tongue does not tend to drag it backwards. Of course, every precaution should be taken to avoid the danger of foreign bodies being aspirated into the air passages. If a post-pharyngeal or tonsillar abscess has to be opened, the pus and blood must be sponged out of the mouth. All loose teeth and masses of growth should be noted, and if possible removed or guarded. When the position of the head has been adjusted, and the other precautions mentioned have been taken, any interference with breathing or duskiness of colour will attract attention. If they occur the mouth must be opened. In some cases this is difficult, as the asphyxial condition causes spasm of the muscles, and the jaws become firmly set. A gag, or mouth opener, can sometimes be introduced in a gap between teeth, and failing this it may be necessary to force out a tooth in order to introduce the mouth opener. When the mouth is opened the tongue should be grasped with forceps and pulled forcibly

out of the mouth, while any foreign body which is seen to have fallen back over the opening of the larynx is seized with forceps and removed. In the case of blood, mucus, vomit, or other liquid, sponging out the back of the pharynx will remove the cause of the dyspnœa. The tongue should be manipulated without roughness. If diseased, and force is suddenly applied, the tongue may be torn, and even if healthy its under surface will be badly cut and lacerated unless care is taken to avoid its being stretched forcibly over the lower incisors. A pad of gauze, or lint, or the corner of a towel should be placed between the lower surface of the tongue and these teeth. In many persons the upper teeth articulate in front of their opponents, and pushing forward the lower teeth will fail to carry the tongue clear of the glottis. It is, however, only necessary under these circumstances to depress the lower teeth by opening the mouth, and then to carry them forward until they are in front of the upper incisors. When this is done the pushing forward of the lower jaw by the finger applied behind the angles of the jaw will keep the air passages open.

When suffocation is being caused by spasm of the larynx, due to the impaction of a foreign body, its relief must at once be obtained by performing tracheotomy, and by sucking out blood clots, masses of growth, etc.*

In any of these conditions, if respiration has actually ceased, it will be necessary to perform artificial respiration as soon as the cause of the obstruction to breathing has been discovered and removed.

Inversion is also of value in cases when it is feared that blood has entered the windpipe. After tracheotomy, sucking the tube is usefully supplemented by inversion.

Insufflation of the lungs by means of a catheter passed through the larynx has been recommended, but it would appear less effectual than tracheotomy and artificial respira-

* An instructive case occurred under my charge at University College Hospital. A man from whom the upper jaw had been removed by the late Mr. Christopher Heath was under operation for a recurrence of epitheliomatous growth, when his respiration suddenly became hampered, and signs of impending suffocation appeared. Tracheotomy was promptly performed, the tube sucked, and several small masses of the growth withdrawn from the windpipe in this way. The man's breathing was restored, and the operation was completed.

tion, aided, when need be, by sucking out blood or mucus from the tracheal opening. When a motor-driven insufflation apparatus is at hand it can be used with every hope of success. Catheterising a bronchus has, it is stated, saved a patient's life when other means had failed. If the foreign body has passed through the larynx and is lodged in a bronchus, it is best, unless asphyxia is imminent, to avoid a hurried tracheotomy. Subsequently a formal operation for the removal of the tooth, or whatever it may be, can be undertaken deliberately and with aseptic precautions.

2. **Asphyxial** conditions occurring during the inhalation of chloroform, and due to other than mechanical causes, are of the greatest importance. While many authorities have contended that such complications do not constitute the only or primary dangers of chloroform, all admit their constant occurrence and extreme peril. Although, as Snow pointed out, actual deaths from failure of respiration without initial interference with circulation are few, yet accidents from interference with respiration are very common and prove fatal unless recognised, as they should be, and promptly dealt with. Further, resuscitative measures, unless very long delayed, should prove successful in most instances of respiratory failure under chloroform provided that the blood pressure has not fallen below a certain point and the protoplasm of the respiratory centre been destroyed by an excessive percentage of chloroform in the blood.

When chloroform at the commencement of an inhalation is presented to the patient in **too concentrated** a vapour **forced holding** of the **breath**, **struggling** and even **spasm** of the **glottis**, may result. There are usually violent movements, the pupils are widely dilated, and the face wears an expression of terror, cyanosis rapidly deepens, and the respiration suddenly ceases. It may be sufficient to withdraw the anæsthetic and compress the chest with the hand, and when respiration is resumed to give it again more diluted and more guardedly. It should be adopted as a rule, that any of the above symptoms demand the immediate withdrawal of the anæsthetic. If, in a deeper degree of narcosis, the vapour of chloroform is allowed to be stronger than can be safely breathed, that is over about 2 per cent., the amount

absorbed into the blood gradually increases, and the patient passes into the fourth degree of narcosis (Snow), weakening of the respiration and duskiness of the skin and mucous membranes ensue, without any warning symptoms except the increasing enfeeblement of respiration. Finally, respiration stops. But this result may arise more suddenly when a patient, already deeply under the anæsthetic, is made to breathe a fresh and inadequately diluted supply of chloroform; the medullary centres then become rapidly over-narcotised and respiration ceases. These forms of respiratory failure are especially liable to occur in individuals suffering from pre-existing respiratory disabilities, *e.g.*, the anæmic, the cyanotic, the emphysematous. Persons who suffer from some condition which interferes with respiration are liable to have their breathing rendered still more difficult as they pass under the influence of chloroform. In cases of cerebellar tumour, spinal disease affecting the upper dorsal or cervical regions; in cases of thoracic disease when one or both lungs are interfered with, such as hydrothorax, œdema of the lungs, or empyema thoracis; and in cases of abdominal tumours when the upward pressure embarrasses breathing, a very small amount of chloroform may actually cause arrest of respiration. There is another type of patient who incurs a similar risk. The danger arises from obstruction in the upper part of the respiratory tract such as may arise, from inflammatory swelling in the cellular structures of the neck, masses of glands, œdema, or abscess pressing upon the trachea, and from goitre. As in the other class of cases to which reference is made above, very small quantities and low percentages of chloroform may prove fatal through interference with respiration. It should be borne in mind that in these cases a vicious circle soon establishes itself. The initial respiratory difficulty leads under chloroform to venous congestion, and this in its turn causes still further interference with breathing.

Treatment.—If the respiration is closely watched and inspiration and expiration are seen to be natural, most of the dangers mentioned above will be avoided. Any deviation from the normal breathing should be observed and adopted as a guide as to whether more or less chloro-

form should be given. When respiration becomes ineffectual or ceases, the chloroform apparatus must at once be taken from the patient's face, the head extended on the trunk, the tongue drawn *out of the mouth*, and artificial respiration by the appropriate method practised. If fluid is in the lungs the Marshall Hall plan should be adopted; in other cases Sylvester's or Howard's method may be used.* The movements must be made deliberately and accurately, and extreme care taken to perform them synchronously with any slight chest movement which nature is able to make. When the patient has a rigid thorax, compression of the abdomen with the view of emptying the lungs by forcing up the diaphragm is an aid to artificial respiration which should not be neglected. For young children and persons whose ribs are easily compressed, the lateral decubitus may be adopted. The hands of the anæsthetist are then so placed as to grasp the upper side of the thorax. Rapid compression and relaxation are then practised, and air is thus made to enter and leave the thorax.

Professor Wood assures me that since he has adopted "forced respiration" he has never seen any fatalities under chloroform. Many apparatus for perflation of the lungs have been invented; perhaps Fell's is one of the best. A tube introduced into one nostril and connected with a powerful foot bellows will easily fill the lungs.† In cases of threatened death from respiratory paralysis I have perflated with oxygen in this manner, or directly through the larynx, and have restored some cases which appeared quite hopeless until I had adopted this measure. Strychnine injected hypodermically (gr. $\frac{1}{80}$ to $\frac{1}{30}$) is usually held to be a valuable adjuvant, but is ineffectual unless artificial respiration is vigorously kept up while the strychnine is absorbed. Hobday suggests hydrocyanic acid as an antidote to chloroform, but the plan has not been used upon human beings, and is probably not devoid of danger. Whether strychnine given in such heroic doses as those mentioned is of much value is an open

* In appropriate cases Schäfer's method should be adopted in preference to the others. These methods are described in Chapter X.

† Great care must be used not to rupture the air vesicles by undue vigour in perflating the lungs by means of the bellows.

question. I am convinced that very large doses such as gr. $\frac{1}{10}$ introduce a fresh danger and should be avoided. It is better to give smaller doses repeatedly rather than one massive dose. Oil of camphor is regarded by some as a safe and more valuable antidote in chloroform poisoning.

(See Chapter X., "Accidents of Anæsthesia.")

FAILURE OF CIRCULATION.

Syncope.—Failure of the heart may occur quite at the commencement of the administration (primary cardiac syncope), that is, after two or three inspirations of chloroform vapour, or it may supervene much later—in the third degree. In the early degree of narcosis, syncope has been variously accounted for; it has been attributed to reflex inhibition of the heart excited by terror, or by the irritation by the chloroform vapour of the sensory nerves of the pharyngo-laryngeal mucous membrane and pulmonary tract; or to an individual susceptibility to chloroform, vaguely called the "chloroform idiosyncrasy." Cases have been recorded of sudden death, provoked by fear, in persons about to be operated upon, who have either taken no anæsthetic, or have imagined, erroneously, they were being chloroformed, while in reality they were inhaling eau de Cologne, or an equally innocuous vapour. Persons may, and no doubt do, faint from apprehension when about to take an anæsthetic. Many deaths have occurred from this cause, so it must not be ignored when considering the perils during anæsthesia, although the anæsthetic may have no direct causal relation to the fatality. It is unquestionably highly important that all perturbing causes provocative of fear, such as loud and technical talking descriptive of the horrors of the operation, should be carefully avoided in the patient's presence. No movement, such as uncovering the field of operation, suggestive of the commencement of the operation, should be permitted until unconsciousness is well established. Fear and trepidation must always be met by kindly reassurance, while haste and brusque handling should be studiously avoided. The commencement of the operation

before complete anæsthesia has been induced is certainly liable to cause syncope by reflex inhibition of the heart.

The imperfectly chloroformed patient is furthermore prone to syncope. It seems probable that inhibition of the heart takes place as a result of stimulation caused by cutting the skin, especially over a sensitive area, and this stimulus is communicated along sensory nerves whose conduction is not yet in abeyance. Records of death in a state of incomplete anæsthesia show how often a fatality arises in cases when trivial, although painful, operations, such as reduction of dislocated limbs, circumcisions, etc., are being performed. During incomplete anæsthesia, the heart is peculiarly liable to reflex inhibition, since the excitability of the vagi, as Embley has shown, is increased in the early degrees of narcosis, and so brings about a rapid fall of blood pressure, which may prove fatal before the heart escapes from the vagal inhibition.

Symptoms.—Extreme and ghastly pallor, with some blueness of the ears and finger-tips, wide sudden dilatation of the pupils, fluttering feeble pulse, and cessation of respiration and of all perceptible heart movements usher in this syncope. There is little or no warning, nor can the most careful preliminary examination give an indication of cases in which this danger is likely to occur. Persons the subjects of fatty degeneration of the heart, of aortic or advanced mitral disease, are always liable to syncope, but the robust and vigorous incur a like risk, and are sometimes the victims of syncope occurring in the initial stage of taking chloroform. Syncope may occur in other degrees of chloroform narcosis (secondary cardiac syncope), but in these cases there is commonly more warning; there is a gradual failing of the heart, evidenced by weakened and often intermittent pulse, pallor, cyanosis, cessation of hæmorrhage; and dilatation of the pupils, with failure of respiration. The cause of syncope, if we exclude surgical shock, hæmorrhage, sudden change in the posture of the patient's body, is probably always an excessive strength of the chloroform vapour. I have never seen it occur when 2 per cent. was being breathed, although I have seen reflex interference with circulation with this strength of chloroform. With percentages above 2 syncope is not

uncommon, and it is usually FATAL when STRONG VAPOURS are in use.

Treatment.—*Chloroform inhalation must be at once stopped*, the patient placed so that his head lies at a lower level than his abdomen, and when possible his legs should be raised, in order to assist the return of blood to the heart and brain. Complete inversion of the patient as practised by Nélaton is certainly the most important remedial measure we possess, but should never be employed when asphyxial complications co-exist with the syncope. The respiration, which will have ceased coincidentally with the cessation of the heart's action, must be kept up by the artificial respiration methods of Howard and Sylvester (see Chapter X.). When syncope is presumably the result of the fall in blood pressure producing bloodlessness of the medulla oblongata, through the blood being collected in the abdominal veins, inversion would, it is pointed out by Leonard Hill, have the effect of still further filling the right heart. He suggests that placing the patient in the feet down position for a moment while the chest is compressed, should help the right heart to expel its blood and fill the arterial system in order that, when the patient is again inverted, arterial blood may find its way to the central nervous system and heart, and so promote their functions. He further insists that if need be the manœuvre should be repeated. Hill's views are supported by sound physiological data which are undeniable. I have had, however, no opportunities of verifying his results. There would seem to be some risk in raising the head of a patient, but possibly this danger is less than that of inversion if, as Hill insists, the blood cannot pass the heart and reach the nervous centres until the right ventricle is relieved of its distended condition.

When, in performing artificial respiration the thorax is grasped in expiration it is well to slip the hand under the costal border on the left side, and so mechanically excite the heart, a method which Koenig has shown to be valuable. The chest and throat, bared of all clothing, should be slapped with a towel wetted in cold water, and fresh air from an open window allowed free access to the patient. Hypodermic injection of strychnine, although of more value when

the respiratory centre is at fault, is regarded by some as a valuable method in all cases of chloroform poisoning. As much as gr. $\frac{1}{10}$ has been given in bad cases, but gr. $\frac{1}{30}$ is usually the dose adopted, although it need hardly be pointed out even this is a large dose of a powerful remedy. Dr. Crile, who has made an experimental examination of surgical shock, asserts that strychnine is useless in small doses, and in large ones may increase the fall of blood pressure and so do actual harm. Digitaline is probably a more efficient remedy, although it is less a respiratory excitant than is strychnine. The injection of brandy in *hot* beef-tea or in warm saline solution by the rectum is a useful measure.

Maas recommends rapid percussion with pressure over the cardiac area. He compresses 100 or 120 times in a minute. Laborde's method of rhythmic traction upon the tongue finds many advocates. The tongue is seized and dragged forward out of the mouth as far as possible, it is then allowed to fall back, and again brought forward, the manœuvre being repeated 16 to 20 times a minute, or even more rapidly. Manskowski advocates and has successfully used intra-venous injections of sterilised freshly prepared **supra-renal extract**. Schäfer regards supra-renal extract as the most powerful constrictor of the vascular system we possess, and places it with nicotine in the front rank among restoratives in cardiac syncope. The best way of employing the former is to mix 1 or 2 drms. of the 1 in 1,000 solution **adrenine** in a pint of normal saline* and inject into a vein or into the subcutaneous cellular tissues.

The inhalation of **nitrite of amyl** is vaunted as a specific, and certainly I have seen it do good in cases of syncope occurring late in narcosis, or after an operation when much blood-loss had occurred. The most convenient way of using the drug is to break a $\frac{1}{2}$ glass capsule and hold it beneath the patient's nose, taking care that artificial respiration is maintained so as to ensure the due entrance of the vapour into the lungs. There seems, however, no satisfactory evidence which proves that amyl nitrite is in any sense an antidote to chloroform.

* Dr. Hare (*Practical Therapeutics*, 1905, p. 537) recommends the following :
Calc. Chlorid. 0·25, Pot. Chlorid. 0·1, Sod. Chlorid. 9·0, Sterilised Water 1,000 c.c.

Among other measures advocated for counteracting this syncope must be mentioned **electrical stimulation** of the heart, and **acupuncture** of that viscus.

One electrode is placed over the neck behind the sternomastoid at about the junction of its lower and middle thirds, while the other is wiped over the præcordium. This plan is, however, open to the objection that the electrical stimulation may produce cardiac inhibition, while it fails to excite the heart muscle. By stimulating the diaphragm to contraction, this method may possibly aid respiration. **Acupuncture** of the ventricle with a gold needle is believed to act by exciting that viscus to contract through direct mechanical stimulation. The cases in which this has been done so far have not been encouraging.

Massage of the heart by direct manipulation has been practised in a considerable number of cases, but without uniform success. In some instances, especially when heart failure has occurred during the performance of an abdominal section, the heart has been grasped from below and compressed rhythmically with a kneading motion of the fingers. In others the abdominal parietes have been divided and access obtained to the heart from below; while in certain cases the more formidable operation of resecting the ribs and a portion of the sternum over the pericardium has been undertaken. The heart movements were restored in all cases, and as long as artificial respiration was kept on the circulation was maintained. In most of the cases, however, respiration eventually failed and consciousness was never restored. Dr. Babcock has used a far simpler method. He makes a stabbing incision on the sternal side of the heart in the left fourth interspace one inch from the sternum, and introduces a finger which is hooked round the apex of the heart, that viscus being rhythmically compressed against the chest wall.

Syncope arising late in the course of an exhausting operation must be counteracted by the methods described above. Brandy may be rubbed over the tongue, lips, and gums, and, as soon as the patient has rallied sufficiently to be able to swallow, given in sips in hot, strong beef-tea. Sinapisms applied over the præcordium, epigastrium, and calves of the legs assist in producing reaction. The head

should be kept low for some hours, and no attempt at sitting up allowed. Hot water, or better, hot saline (at 110° F.) injections into the bowel are of great value; they must be copious and may be repeated. Reaction is aided by hot water bottles applied to the feet and sides, and the flow of venous blood is promoted by firm rubbing of the limbs from the feet and hands towards the trunk. Inversion of the body, so that the feet are in the air, is often of signal service in extreme cases of cardiac weakness, *when there is no reason to believe that the right side of the heart is engorged*. Sniffing "smelling salts" or ammonia vapour will often assist, but the latter must not be too strong or it will excite spasm of the glottis. Bandaging the lower limbs and abdomen and firm pressure over the abdominal aorta are useful in these cases.

During abdominal sections patients are especially prone to syncopal attacks under chloroform. These are due (1) to interference with the normal intra-abdominal pressure; this occasions draining into the abdominal veins, and hinders the passage of blood into the heart; (2) reflex interference with the heart arising from dragging upon the viscera, and especially from pulling upon the omenta and reflexions of the peritoneum. As soon as the parietes are sewn together again the patient's condition improves.

Epileptic and epileptiform seizures are very liable to occur as patients pass under the influence of chloroform. Beyond transitory weakening of respiration and fall of blood pressure, as a rule no ill consequences occur. It is well in the case of known epileptics to place a gag in the mouth to avoid the tongue being bitten. The anæsthetic should be withheld during the fit.

AFTER EFFECTS OF CHLOROFORM.*

Bronchitis occasionally follows the inhalation of chloroform, and must be treated on general principles. In all such cases it is difficult to eliminate contributory circumstances, *e.g.*, exposure, chilling of the body, etc. Lung complications may follow the use of partly decomposed chloroform (*vide infra*).

* For the medical treatment, see also After Effects of Ether, Chapter IV.

Vomiting.—If attention has been paid to the directions given when dealing with "The Preparation of the Patient," vomiting will be rendered less liable to occur. The following further directions will tend to the same end. Biliary, plethoric persons should have their bowels well cleared before taking chloroform and should be accurately dieted for some days before. The patient's head should be kept quite low; he should not be moved from the operating-table for half an hour after coming to himself, and then the utmost care must be taken to prevent his being shaken, or his head raised.

Opium should not be given by the mouth; and unless there is obvious and urgent shock, brandy, ether, and sal volatile had better be withheld. Nor should food be taken, whether liquid or solid, for at least three hours after chloroform, and even subsequently abstinence from everything except hot water, which may be taken copiously if vomiting or nausea is troublesome, is best for six hours or so. Meat jelly, bread boiled in milk to which a pinch of bicarbonate of soda is added, or sponge cakes soaked in a light dry sherry, may be permitted after this time; tea, coffee, soaked toast, may be tried, but all indigestible or solid food should be denied.

In cases of persistent vomiting or nausea sips or draughts of very hot water will give most relief, especially if made slightly alkaline with bicarbonate of soda. Thirst is sometimes a painful after effect following very prolonged operations. This is especially so after abdominal sections. Copious enemata of hot water, frequently repeated, are of value. Lavage, performed at the close of the operation and before consciousness returns, is often most valuable, especially for persons who are prone to severe sickness. Drop doses of Tr. Nuc. Vom., well diluted with hot water, are certainly useful in less severe cases. Mackenrodt soaks a towel or handkerchief in vinegar (preferably cider vinegar), and arranges it so that the patient inhales the fumes. He finds it checks sickness and assists elimination of the chloroform. In obstinate vomiting sinapisms over the stomach, small doses of Cocaine Hydrochlor. (m v. of 5 per cent.), oxalate of cerium, and codeia are valuable. Chloretone

(Chlor.-butyl) has been vaunted for the purpose of checking sickness, but it is less valuable when given *after* chloroform than when administered in gr. xv. doses one hour and a half before the inhalation.

Fifteen-grain doses of Aspirin given by the rectum immediately after the completion of an operation sometimes checks the tendency to vomiting in nervous persons and produces a refreshing sleep.

Dryness of the tongue, sometimes a troublesome complaint in the post-anæsthesia stage, is greatly relieved by Tinct. Myrrhæ, Glycerin. Boracis, or by sucking a cloth soaked in Glycerin. ʒj. also Spir. vin. rect. and water in equal parts, ʒij. (Kelly). Thirst and tongue dryness, especially frequent after operations upon abdominal viscera, are best treated by copious rectal injections of warm water given every three or four hours. It is stated, but I have no personal experience in the matter, that if patients are allowed to drink hot water up to two or three pints previous to the time that the anæsthetic is inhaled, they are less sick and suffer from no nausea. The last glass of water is allowed half an hour before the anæsthetic. When morphine is given after chloroform has been inhaled, vomiting is certainly worse. It is altered in type, usually occurring after an interval of some twelve hours or so, and is commonly very severe.

Post-operation shock, in so far that it may in part be due to the anæsthetic, needs careful attention. The patient lies cold, with clammy extremities, feeble pulse, and faint, sometimes irregular, respiration. Consciousness is slow in returning. The horizontal posture, application of warmth to all parts of the body, enteroclysis, rubbing brandy into the lips and buccal pouches, with constant friction applied to the legs and chest are the best means of restoring the patient. I have found hypodermic injections of strychnine, and oxygen inhalations of the greatest value in these cases. In extreme conditions of shock transfusion of normal saline is called for, and will often restore an apparently hopeless case. Poncet has drawn attention to the dangers of the period of recovery from an anæsthetic. In more than one case patients whose respiration failed owing to malposition after they were placed

in bed were recovered by his performing tracheotomy and ventilating the lung through the aperture so made. This plan succeeded when all the ordinary measures, *e.g.*, artificial respiration, etc., had been tried and failed. Poncet explains the mechanism by which death is averted in these cases by the following ingenious hypothesis. Under normal conditions the lungs are expanded sufficiently to overcome the resistance caused by their elasticity and the obstruction in the air passages. Under an anæsthetic, while some inspiratory power remains, the expirations grow rapidly more feeble. The muscular structures undergo paresis. At this point even a slight obstruction, fixation of the jaws, falling back of tongue, glottic spasm, or a collection of mucus, will be too much for the respiratory mechanism to overcome, and asphyxia results. Tracheotomy, although but slightly increasing the patency of the air way, will, Poncet believes, by allowing *cold* air to enter, excite reflexly renewed and more vigorous respiratory movements.*

After effects due to decomposition of chloroform during operations undertaken by gaslight are those arising from inhalation of irritant gases—phosgene gas, chlorine, hydrochloric acid fumes—and the treatment consists in assisting the elimination of the gases by opening windows, etc., and allaying the bronchial spasm by bland inhalations, while the concomitant shock is treated on general principles. The danger is increased when the room is small and when the atmosphere is foggy. Several deaths have occurred, resulting from phosgene gas poisoning.

Hysteria.—Fits of hysterics are sometimes excited in the neurotic by chloroformisation; no special treatment need be adopted. These attacks seldom last more than three or four hours, and should cause no alarm. In rare instances such seizures simulate acute mania, although these attacks are more common after the use of ether. The greatest care has to be exercised to avoid the patients doing themselves damage in their struggles. Sedatives given by the rectum or hypodermically are called for in really bad cases. They may occur in either sex.

Jaundice and general biliary derangement in some in-

* See *Lyon Médicale*, Jan. 13 and June 16, 1895, pp. 35, 49, and 226.

stances follow chloroform administration, especially after prolonged or repeated administrations. They should be treated upon general principles, and usually need give rise to no alarm.

Albuminuria and glycosuria may follow the use of chloroform. According to Baixer, diabetics are injuriously affected by chloroform. In 24 or 48 hours they become restless, then drowsy, and finally pass into coma and die. These results are not by any means the rule, as I have repeatedly given chloroform to such persons without bad results. It is important, however, to limit both the strength of the vapour and the actual amount given and to use oxygen *pari passu* with it. The time during which the inhalation is continued should be curtailed as much as possible.

Upon the renal epithelium, chloroform excites a marked action. Legrain found albuminuria and cylindruria fairly common after chloroform inhalation, and more persistent although less in amount than after ether. Thomson and Kemp are led to believe, as a result of oncometric observations, that suppression never follows the inhalation of chloroform, and that the albuminuria is slight and transient. Wunderlich, Alber, and Rindskopf, however, agree with Legrain. When pre-existing renal disease is present, chloroform should be given very sparingly, to limit its action on the kidneys. Working with the oncometer I found in the case of dogs that the results of chloroform upon the kidneys were materially affected by the strength of the vapour given. No special treatment is, as a rule, called for in chloroform nephritis.

Delayed chloroform effects (Acidosis).—An extremely curious sequela has been closely studied by Leonard Guthrie in this country, and by Brackett, Stone and Low, Baird, Favill and Bevan in America, and by many workers abroad. It has been known for a long time that a degeneration of the liver and other viscera takes place in dogs when they are compelled to inhale chloroform at frequent intervals. It is now recognised that similar pathological changes, affecting especially the liver, kidneys, heart, and muscular structures, may be brought about under certain unknown conditions in human beings, as a result of even one inhalation of chloroform.

The symptoms usually appear between the 12th and 42nd hours after the inhalation. They are: repeated vomiting of foul watery fluid, which later is brown, and resembles dregs of beef tea; restlessness, delirium, or excitement, alternating with an apathetic state, which may deepen into coma. The breath has a strong odour of acetone. The urine is scanty, albuminous, contains casts, while acetone, diacetic acid, or β -oxybutyric acid are sometimes present. At length respiration and circulation fail, and death closes the scene. How far chloroform is responsible for the development of this condition it is impossible to say. It is clear that the anæsthetic is not the sole factor, as out of the many thousands of persons who inhale chloroform, extremely few patients reveal the symptoms of acid intoxication with its pathological lesions. Nor can we trace any antecedent condition common to the patients. It is true that more instances of children so affected have been reported, but this may be explicable upon other grounds. The main points of practical importance seem to be that *limiting the amount of chloroform inhaled and restricting the strength of the vapour* are the surest safeguards against acid intoxication in chloroformed patients. The treatment of these cases has been carried out on general lines, and in some instances has proved successful. The most recent work done upon this subject appears to warrant the belief that the condition arises through interference with carbohydrate metabolism, and that the most hopeful treatment is to give glucose either by the bowel (3i. to 3vi. of saline) or by the mouth. The phrase "delayed chloroform poisoning" is a bad one, because the condition may follow ether or ethyl chloride, and, indeed, as Dr. Frew* has shown, changes in diet will induce acidosis in poorly nourished children. I have discussed this subject more fully in a paper contributed to the *Transactions of the Medical Society*,† and to this the reader is referred. Dr. William Hunter's work upon this subject is of great value; he appears to regard the perversion of function as largely due to injudicious food selection and limitation, and to place the effect of an anæsthetic as one factor only and that not a dominating one in causing the acid

* *Trans. Roy. Soc. Med.*, Section "Anæsthetics," 1912.

† Vol. xxxv., p. 280. See also *Lancet*, May 11, 1912, p. 1267.

intoxication. It is interesting, in this connexion, to notice the—

Effects of repeated inhalations.—Paul Bert made a careful study of the effects of daily administration of chloroform for a definite time. His researches were made upon dogs. After gradual failure of health, these animals died on the 32nd day with well-marked wasting of their organs and muscles, and fatty changes in the liver. Paraspоро (*// Policlínico*, Dec., 1897) has repeated these experiments and met with similar results. He further reports finding a similar fatty change in the tissues of a woman who died from an over-dose of chloroform. According to J. Regnault and Dubois (quoted by Dastre), workers constantly exposed to the fumes of chloroform suffer from insomnia, with neuralgic and rheumatic pains, as well as marked physical and mental depression.

ASTIGMATISM and INSANITY, although recorded as after effects of chloroform inhalation, are probably the results of general disturbance.

CHLOROFORM IN VETERINARY SURGERY.

It is hardly necessary to emphasise the importance of using anæsthetics in most operations upon the lower animals. In the case of horses, dogs and cats especially, surgical procedures can be better done while shock is lessened when anæsthesia is complete. It is equally important if valuable lives are to be saved that dosimetric methods should be employed. The animals are supremely affected by strong vapours, and they are also liable to fatal syncope when in a semi-conscious condition. Mr. Hobday's apparatus fitted with appropriate face masks is better than the douche method and the bucket masks commonly employed, and should be adopted in preference to these. In the case of small animals which are savage it is often necessary to induce anæsthesia while the patient is in a box, but even then it is quite simple to pump in the required strength of vapour and maintain anæsthesia by means of the mask when the animal has been removed from the box.

One form of the Hobday apparatus is shown on p. 254.

CHAPTER VI.

ETHYL CHLORIDE AND ITS MIXTURES— ETHYL BROMIDE AND LESS COMMONLY USED ANÆSTHETICS.

Ethyl chloride (Chlorethyl) is employed both as a local and general anæsthetic.

Preparation.—Ethyl chloride, C_2H_5Cl , is prepared by passing carefully dried hydrochloric acid gas into a flask containing absolute alcohol to which coarsely powdered anhydrous zinc chloride has been added; the zinc chloride is a powerful dehydrating agent, and combines with the water produced during the reaction.

The flask is fitted with a reflux condenser, and is gently warmed on a water-bath; the gaseous ethyl chloride is passed through wash bottles to purify it, and is then collected in a U-tube immersed in a freezing mixture.

Physical and chemical properties.—Ethyl chloride is a gas at ordinary temperature and pressure, but when slightly compressed it is a colourless mobile liquid with a pleasant ethereal odour. Sp. gravity about 0.921. Boiling point $12.5^{\circ}C$. It is very inflammable and burns with a smoky, green-edged flame.

It is generally kept in glass tubes, sealed, and fitted with a spray nozzle.

It should be free from hydrochloric acid and alcohol. The following are the principal tests:—

Hydrochloric acid.—10 c.c. dissolved in a little alcohol should produce no turbidity when added to a solution of silver nitrate.

"Smell" test.—When 10 c.c. are sprayed upon filter paper no foreign odour should be perceptible during the evaporation and when all the ethyl chloride has volatilised the filter paper should be quite odourless. This test will usually detect impurities occurring through careless storage.

Alcohol test.—When 10 c.c. are shaken with 10 c.c. of distilled water, the lower aqueous layer boiled with a few drops of diluted sulphuric acid and a few drops of potassium dichromate solution, should develop no odour of aldehyde, and no greenish colour should be produced in the liquid.

Ethyl chloride is also known under the trade names Kelene and Chloryl Anæsthetic.

Mixtures of methyl and ethyl chlorides are more volatile than pure ethyl chloride; such mixtures are supplied under the trade names Anestile (Anæsthyl) and Coryl.

History.—Although ethyl chloride has been adopted as a general anæsthetic only within the last few years, it was known and employed as early as 1848 by Heyfelder. Benjamin Ward Richardson included it in his "Synopsis of Anæsthetics," published in 1885, and gives 1849 as the date of its introduction by Nunneley, and 1852 as the year in which, conjointly with Snow, he demonstrated its value as an anæsthetic. The "Glasgow Committee" of the British Medical Association examined its action upon the lower animals and arrived at the conclusion, which they formulated in their Report published in 1880, that it was unsuitable for human beings, as it produced convulsions and respiratory failure. Its restoration to favour was due to the observations of Carlsen and Miesing, who, when employing it as a local analgesic, found it induced general anæsthesia. Lotheisen used it systematically as a general anæsthetic, and to his writings we owe much of our knowledge of this agent. The disrepute into which the drug had fallen was due to the impurity of the samples examined, and even now certain of the preparations give unsatisfactory results, so that care must be taken to obtain the anæsthetic from reliable makers. Some of the foreign manufacturers have attached fancy names to ethyl chloride and its mixtures: it need hardly be pointed out that this procedure is undesirable, and suggests that their preparations possess special powers; while it masks

the character and properties of the drug employed, the use of which the advertisers are apt to vaunt as free from every sort of difficulty and danger.

Physiological action.—Profound narcosis, with complete anæsthesia, is rapidly produced when ethyl chloride is given and air is carefully excluded. No very complete research into the action of this anæsthetic has been yet undertaken. Lebet, working with Dumont of Berne, found that intravenous injection produced in the case of rabbits marked circulatory depression. This agrees with the results at which Wood and Cerna arrived. Malherbe and Roubinovitch investigated the effects produced upon the arterial tension in man by means of Potain's sphygmomanometer, and found it was lessened in most cases. Koenig's results are in accord with their finding; and McCardie, who in this country has done much valuable pioneer work upon this subject, has satisfied himself that a fall of blood pressure takes place when ethyl chloride is given even for a short time. Seitz's sphygmographic results reveal a rise of arterial tension. Probably the truth lies between the extremes of opinion, and some observations of Koenig may explain the discrepancy. He found that when air was completely excluded arterial tension rapidly fell, and death ensued from failure of respiration and circulation. In clinical work this exclusion of air is either avoided altogether or only practised for a very brief time, so that the arterial pressure does not undergo any material change.

Flushing, due to dilatation of peripheral vessels, is always associated with ethyl chloride inhalation, and may account in part for any fall in blood pressure which may take place. Respiration is profoundly affected, but this is possibly secondary to the changes in the circulation, except perhaps when large doses are employed. Seitz, however, takes the opposite view, believing respiration to be affected first. Respiratory paralysis and failure of the heart's action result from the inhalation of a full dose of this drug, especially when the supply of air is much limited. Koenig asserts that in complete anæsthesia vagal inhibition is abolished. The nausea and vomiting which so frequently follow the use of this anæsthetic are probably due to reflex causes rather

than to a direct irritant action upon the mucous membrane of the stomach. Its action is very fugacious; patients rapidly lose and soon regain consciousness. Its elimination takes place mainly through the lungs; but, as Lebet has found slight albuminuria to occur, it is probable that when given for a prolonged period some of the drug passes through the renal tissues. Its action as a local anæsthetic is due to its causing ischæmia, and paresis of the terminals of the sensory nerves.

Danger and death rate.—It is extremely difficult to arrive at an accurate estimate of the safety of ethyl chloride. Ware collected 11,207 cases and reported one death. Seitz and Konstanz place the death rate at 1 in 16,000. Several deaths have occurred in Great Britain. It is certain that ethyl chloride is less safe than nitrous oxide, and must be placed between ether and chloroform in the case of normal patients, but may be regarded as possibly safer than ether when lung and kidney complications exist. Some authorities, however, assert that ethyl chloride is safer than nitrous oxide and other anæsthetics when given to quite young children. Our present knowledge of ethyl chloride makes us recognise that it is by no means so safe as at one time it was believed to be. In the hands of the experienced it is no doubt a fairly safe anæsthetic, but not one to be employed by the inexpert and incautious. McCardie's experience tends to confirm the view given above as to the safety of ethyl chloride, and he very wisely insists upon our recognising the limitations of its range of usefulness. My own experience, which is now extensive, leads me to believe that ethyl chloride is comparatively safe in suitable cases when properly given, but may easily produce serious symptoms. I have never seen a death, but have experience of two cases in which an alarming failure of respiration and circulation occurred. One patient was somewhat anæmic, but both were in average health, and there was nothing in the operations themselves or in the respective circumstances of these cases to have occasioned syncope. In each case complete anæsthesia was present, and a full dose of the anæsthetic was employed. The occurrence of serious complications, such as syncope, which in one case ended

fatally, has been recorded by Ware, Lothiesen, and others. Respiratory failure is probably the most common accident, certainly so in the case of children, but danger may arise from the side of the circulation and is then more serious.

Preparation of the patient.—This should be the same as in the case of chloroform or ether. It is advisable that food be abstained from for four hours, and the last meal taken should be light and digestible.

Posture.—Unless the patient is very asthenic, any posture, sitting or reclining, may be adopted. The clothing must be loose, and everything which interferes with breathing removed.

Administration.—Ethyl chloride may be given by an "open," and by a closed method.

The open method.—A wire mask covered with one layer of flannel is fitted accurately to the patient's face. A light towel is thrown over this after the ethyl chloride has been dropped on the mask. The tube of anæsthetic is arranged to drop by placing a tiny mass of cotton wool "the size of a quarter of a small split pea" beneath the lever which closes the minute outlet of the stopcock.

The tube is tilted and ten drops of ethyl chloride allowed to fall on the mask. After a few seconds double this quantity is applied, care being taken to scatter the drops over an extended area of the mask. If this is not done freezing will occur, checking all evaporation. This procedure is repeated until unconsciousness supervenes. Anæsthesia is induced in about one minute and persists sufficiently long to enable a brief operation to be performed. Mr. Hornabrook of Melbourne, whose method is described above, assures me that few if any unpleasant after effects arise and that he seldom has seen vomiting or discomfort. According to this observer a period of local analgesia follows the anæsthesia, enabling the operation to be completed even when the patient becomes conscious. 8 to 10 c.c. is an average dose by the open method; the resulting narcosis is light but adequate. The patient should be sitting up with the head placed in the axial line. When this method is adopted for longer operations a few drops of chloroform are used immediately after the ethyl chloride, and these are followed by ether given by

the open method. It is alleged that full surgical anæsthesia is thus obtained in two or three minutes. This plan has been carefully elaborated by Dr. G. A. H. Barton.* He commences with a little C.E. mixture, then uses ethyl chloride, and follows on with chloroform. It is well to place an unopened gag between the teeth before commencing the inhalation, opening it just before the operation.

The closed method.—This method involves the use of an inhaler; those depicted and described below are simple and efficient. The first, which has been modified by Dr. Beresford Kingsford from Mr. Boyle's wide-bore inhaler (with lint lining the inside of the mask), ensures that the breathing shall be free and unrestricted. The "Ideal" is the suggestion of Mr. Vernon Knowles, and is supplied with his reversible rubber bag which enables the anæsthetist to ensure cleanliness in his work. The "Simplex" is from the design of Dr. Luke, of Edinburgh, and is excellent.

Many inhalers, too numerous for mention and each possessing some merit, are to be obtained. Of these several are simple adaptations of Clover's regulating ether inhaler. When no special inhaler is employed, a ready substitute can be made by having an opening bored into the metal-carrying mount of the rubber bag of the "Clover," to allow of the ethyl chloride being introduced into the bag. The aperture can be closed by a wooden plug. The mount carrying the bag is then fitted directly on to the face-piece, the ether chamber being discarded unless the sequence of ethyl chloride and ether is to be employed. The opening made in the mount serves for spraying in the ethyl chloride; it is made just large enough to take easily the nozzle of the stop-cock on the ethyl chloride tube. It is quite simple to make an inhaler from lint or a towel folded into a cup-shape; although, as a rule, the device is less satisfactory, it serves its purpose fairly well in the case of very young children, and in that of extremely nervous patients, who dread the application of any apparatus.

Ethyl chloride may be given also: (1) in sequence with nitrous oxide; (2) in sequence with ether; (3) before chloroform; (4) in various mixtures. These last are:

* *Pract.*, Sept. 1907.

various admixtures of methyl and ethyl chlorides ; mixtures containing these with ethyl bromide added.

Indications and contra-indications for its use.—Ethyl chloride may be used for children from five days old and upwards with good results.* I have employed it for the aged † as well as the very young, and that without difficulty or danger. Dr. McCardie considers that conditions causing blocking or stenosis of the air passages are contra-indications, and with this I agree. Among diseased subjects my experience is that, while no chronic or acute disease, as such, is a contra-indication, yet lung diseases involving marked respiratory difficulty, especially when associated with bronchorrhœa, are liable to cause dangerous developments when ethyl chloride is given. In a case of aortic aneurism in which I administered this anæsthetic, the narcosis was free from any unfavourable symptoms.

When complete muscular relaxation is required, my experience has not been in favour of ethyl chloride. Dr. McCardie, whose experience is extensive, does not agree with this view, and contends that, with care and an adequate dose of the drug, muscular relaxation can be usually obtained. Spraying a few c.c. of ethyl chloride on the open mask when chloroform is in use is said to hasten relaxation (Rowell), and the like result follows in the case of ether given similarly (Kingsford). I have no experience of ethyl chloride in midwifery practice, but it has been employed, and, it is stated, with success. Alcoholic persons are not good subjects for ethyl chloride. They are apt to become extremely violent, and often the anæsthesia in their case is very brief. In some instances it is extremely difficult to produce a satisfactory and quiet anæsthesia in such persons, even when using a large dose, *i.e.* 10 c.c. Smokers suffering from pharyngeal catarrh do not always take this anæsthetic well ; they are liable to cough, strain, and struggle for air. When the heart's action is feeble and the weakness is probably due to fatty degeneration ethyl chloride is contra-indicated.

* Dr. Flora Murray adopts it as a routine method in such patients and speaks enthusiastically of it, *Lancet*, Nov. 25, 1905.

† In the case of those advanced in years great care is needful, and the recumbent posture a *sine quâ non*.

DESCRIPTION OF INHALERS.

Wide-bored inhaler.—In Dr. Beresford Kingsford's improved form of Mr. Boyle's inhaler there is no lint in the face-piece, so that the patient's face can be seen throughout the administration. The neck of the bag fits over that of the face-piece, and can be freely rotated about it. Corresponding openings are made in the inner and outer necks, and when these coincide the anæsthetic can be sprayed through them into the bag. Within the neck of the face-



FIG. 70.—Wide-bored ethyl chloride inhaler (Kingsford).

piece lint was formerly fixed (opposite the aperture) by a clip, so as to form a pocket which is open towards the bag, just as an aortic valve forms a pocket open towards the aorta. The lint minimises reflux of the spray into the face-piece, and economises the anæsthetic. When a gag is used the inhaler can be applied *uncharged* the moment the gag is adjusted, and then can be charged during a convenient expiration. After a breath or two the air-way is closed by slightly rotating the neck of the bag.

The "Ideal" is constructed to enable the administrator to give ethyl chloride freely diluted with air. I have little doubt, from my experience with this inhaler, that the prin-

ciple is a correct one. It is the suggestion of Mr. Vernon Knowles, and is most useful.

Another useful form invented by Dr. Luke is figured, and needs no explanation. It is called the "Simplex."

The inhalation (1) for short operations, *i.e.* such as can be performed when one, or at the most two, inhalations are allowed. The patient should be seated comfortably, his body and legs disposed as in the case of nitrous oxide (see p. 77, Plate II.). A dental gag should be placed securely in position, and the face-piece carefully applied with the supply aperture open. There must be most accurate coadaptation, so that *no air enters under the inflated rim of the mask*. A few breaths having been taken, 3 c.c., in the case of an adult, are then sprayed into the bag at the end of a forcible expiration. The inlet is then closed, and the patient encouraged to breathe freely. If he holds his breath, as may happen with nervous patients, the chin should be sharply jerked upwards, as this induces an inspiration. After fifteen or twenty seconds, when the breathing has become fuller and more rapid, the inlet is again opened during an expiration, and 2 c.c. more of ethyl chloride are sprayed in. If a prolonged anæsthesia is desired, and the patient is vigorous and full-blooded, 3 c.c., or even 4 c.c., may be given instead of the 2 c.c. The plan of dividing the dose, which I have adopted and described, is based upon the following observation. Patients when they commence breathing ethyl chloride often



FIG. 71.—The "Simplex" inhaler* (Luke).

* Made by Messrs. Duncan & Flockhart.

breathe feebly, and do not inspire the full dose from the bag. As, however, they become partly narcotised the respirations grow more vigorous, and the second dose, which is then sprayed into the bag, is inspired freely, and thus a good and prolonged anæsthesia is ensured. In thirty to sixty seconds from the commencement of inhalation the breathing will become loudly and musically stertorous.

The stertor deepens; in most cases the eyeballs will be fixed—being usually rotated downwards—and the pupils dilated; the anæsthesia is then complete. The degree of insensibility is very profound, yet, if the anæsthetic is withdrawn as soon as well-marked stertor is present, it deepens for a few seconds afterwards. This deepening of narcosis after the mask is withdrawn is very considerable in children of any age under seven years. It will often happen that if the mask is withdrawn while the child is still crying, and the operation (a short one) is commenced, insensibility becomes more complete. There is no corneal reflex, the crying subsides, and the reflex will only return after an operation has been performed without evoking a struggle or sign of consciousness.

If, in such young children, the anæsthetist waits for cessation of crying, or is induced to give more anæsthetic to effect deeper narcosis, failure or danger from over-dose will certainly be incurred. The duration of anæsthesia is usually from one to three minutes. In one instance I obtained a period of five minutes' anæsthesia, using 8 c.c. of the anæsthetic.

That the action of ethyl chloride is very fugacious is shown by the rapidity of recovery. For a few seconds after anæsthesia ceases the patient is dazed and has little control of himself or his movements, but this is followed by restoration to complete consciousness. In these respects ethyl chloride resembles nitrous oxide and contrasts with chloroform or ether narcosis. As soon as stertor begins, the mask should be removed and the operation commenced, for if the anæsthetist delays removal of the mask with the view of obtaining a longer anæsthesia, he will find, to his chagrin, that during the delay the ethyl chloride has partly or wholly

become dissipated and consciousness is returning.* If, after the inhalation has lasted 60 seconds, there is no stertor, more anæsthetic must be given, as the narcotic effect is never delayed beyond this point. It is important to remember that the narcosis, while it lasts, is very deep and the reflexes are in abeyance, and thus operations on the upper air passages involving hæmorrhage may prove dangerous (or even fatal), unless care is taken to direct the blood out of the mouth.

(2) Prolonged operations. Although the consensus of opinion is not in favour of the use of ethyl chloride for longer operations, except sometimes in the case of young children, yet it may be well to indicate the technique of its management for operations of from five to twenty minutes' duration.

The patient must be carefully prepared, just as in the case of ether or chloroform. The induction is conducted as has been described already, and when anæsthesia is obtained the mask is either removed or the inspiry valve opened, the patient being permitted to ventilate the lungs with air. As soon as stertor disappears and the eyeballs commence to move, 3 c.c. or 4 c.c. are sprayed into the bag. This is repeated as often as may be necessary to maintain anæsthesia.

It is seldom advisable to give more than 5 c.c. at one time, although in the case of alcoholics and vigorous men it may be necessary to use 3 c.c. or even 5 c.c. after the initial dose before anæsthesia is obtained. As a rule, 3 c.c. are sufficient for children and 5 c.c. for adults. It is, however, important to ensure that this dose really enters the patient's lungs. To this end the mask must fit accurately, the patient must be encouraged to breathe freely during the induction, and the respirations must be sufficiently vigorous to nearly empty and refill the bag. Children, especially young and feeble children, cannot do this, and so when the anæsthetic is not sprayed upon lint or a sponge near to their mouths they do not get enough of it. This difficulty is met by the lint in the inhaler, but it can easily be overcome by placing the hand under the bottom of the bag of the inhaler; this volatilises the ethyl chloride.

* It is often very difficult to avoid slight leakage between the mask and the face of the patient, and even if this is very slight, it will be sufficient to dissipate the anæsthetic.

Ethyl chloride in operations upon children.—Dr. Flora Murray * regards this anæsthetic as preferable to chloroform for children. A simple bag with celluloid face-piece, fitted with a wire holder to keep a piece of lint in position and an aperture in the connecting shaft, is all that is required. A dose of 3 c.c. is suitable for infants of a few months old and 5 c.c. for children a few years old. The mask is held near, but not touching, the face for the first breath or two. The ethyl chloride is sprayed on to the lint; it is then applied closely. The child should **not** be held more than is necessary to prevent his hands from clutching the inhaler. Stertor appears in a few seconds, the eyeballs are fixed, and deviation is commonly seen, the pupils are variable, the respirations rather rapid and deep. As recovery comes on these grow slower and more shallow. Repeated doses may be given, respiration being closely watched. If it begins to fail, the chest should at once be compressed and the anæsthetic withheld until breathing is fully restored. The after effects are usually slight.

METHODS OF GIVING ETHYL CHLORIDE IN COMBINATION.

With nitrous oxide.—This combination has been suggested, and it is regarded by some authorities as possessing special advantages. †

The ethyl chloride is sprayed into a tube or bottle, which is attached by an india-rubber tube to a tap in the distal end of a Cattlin's gas-bag after this latter has been partly filled with nitrous oxide. Experience is necessary to gauge the quantity of gas requisite for each patient. The patient inhales the gas, and after a few respirations the expiry valve is closed, and rebreathing takes place for a few seconds; then the stop-cock is opened and the ethyl chloride is allowed to evaporate, or, if necessary, is tilted into the gas-bag. My experience of the method has not convinced me of its superiority over simpler procedures, except when it is desirable to give a

* *Lancet*, Nov. 25, 1905, p. 1542.

† Sir F. Hewitt introduced this method at the Annual General Meeting of the British Dental Association, June 1903. See *Brit. Dental Assoc. Jour.* for 1903, 615.

patient nitrous oxide because he is already familiar with it, and yet obtain the more lasting and profound anæsthesia of ethyl chloride.

With ether.—It may be used instead of nitrous oxide as a means of introducing ether. In the event of a closed ether inhaler being used, the method is quite simple. The induction by ethyl chloride is as described above, and ether is given as soon as stertor is well marked, at first in moderate strength, but rapidly increasing it to "full ether." Cyanosis may be produced if the ether is presented too soon, and is always a warning that a breath of air must be given. If an "open ether" method is to be used it is better to use a few drops of chloroform to deepen narcosis before commencing the ether. This system is described on p. 174. Before these sequences, alkaloids may be advantageously employed.

Difficulties and dangers.—The dangers are interference with circulation and respiration. Very young children occasionally stop breathing during the period of induction. This, possibly, is the result of over-stimulation of the respiratory centre. The explanation is not, however, quite satisfactory, since blood pressure in such cases is distinctly low; but from whatever cause it arises, the complication, though an alarming one, fortunately seldom proves serious. The removal of ethyl chloride, lowering the head, and compression of the chest rapidly restart respiration.

In adults embarrassment to respiration, cyanosis, faintness or syncope may occur. Such accidents may arise through giving a large dose, such as 8 c.c. or 10 c.c.; lack of attention to the correct posture for carrying on unimpeded breathing; or from collateral circumstances which interfere with respiration, such as falling or pressing back of the tongue, *e.g.* during the extraction of lower teeth. Blood passing backwards to the larynx is again a cause of such dangers. Cyanosis, pallor, rapid, shallow, and laboured breathing, should be watched for and at once recognised as a warning of danger. The anæsthetic should be withdrawn, the jaw should be pushed forward, and if need be, the tongue should be seized and traction made upon it while the head is lowered. In extreme cases, when there is actually cessation of respiration and of circulation, the patient should be placed

in the horizontal position and artificial respiration performed, the tongue being held forward and the upper air passages cleared of blood and secretions. Young children should be placed on their right side, and the chest rapidly compressed. If these measures fail, laryngotomy must be performed. The fatalities which have occurred have been due to the failure of circulation and respiration.*

After effects.—Vomiting and nausea are more frequent after ethyl chloride than after nitrous oxide inhalation. This is partly accounted for by the profoundness of the narcosis, which allows the swallowing of blood and mucus. Provided that by attention to the position of the head and by efficient sponging out of the fauces this does not occur, it will be found that vomiting is by no means a necessary sequela.

In dental hospital practice I found 9·6 per cent. of patients vomited, and to these must be added 4·8 per cent. of cases in which there was some nausea or retching. The cases examined were not prepared for the anæsthetic; some had taken a meal, several had taken alcohol just before entering the hospital. It must be pointed out further that, in these cases, extensive dental operations were carried out, involving the removal of several teeth, and the blood effused was swallowed during the progress of the extractions before the patient was aroused, so that the figures given are probably the most unfavourable which could be cited.

There does not appear to be so much headache or persistent vomiting as after ether or chloroform; nor is the after bleeding increased when ethyl chloride is inhaled. It has been stated that the immediate hæmorrhage is increased, but this is not always the case.

MIXTURES CONTAINING ETHYL CHLORIDE.

Of these the best known are somnoform (sometimes spelt scœmnoform or scœmnoforme), narcotile, kelene, and anæstile.

* Cf. *Transactions of Soc. of Anæsthetists*, vol. vii. pp. 91, 99, 103, 119, 129. See also below Chapter X., "Accidents of Anæsthesia." A recent death under ethyl chloride may be mentioned here. The patient, aged 67, was given 5 c.c. for a dental operation, and died before its completion. It was discovered at the necropsy that he had a "fatty heart." Unless the patient is hale, and has no infirmity of circulation and no respiratory embarrassment, ethyl chloride should not be given to the aged, and certainly only in the recumbent posture.

Kelene, narcotile, and anæstile are either ethyl chloride pure and simple, or are mixtures of it with methyl chloride.

Somnoform * is composed of methyl chloride 7 parts, ethyl chloride 12 parts, and ethyl bromide 1 part.

Sydney W. Cole † has undertaken, under strictly scientific control conditions, a research into the physiological action of this mixture, and finds its behaviour is in the main that of ethyl bromide. Dr. Swan ‡ has also conducted a limited research, while the originator of the mixture § has published his views on the action of somnoform.

Mr. Cole found somnoform increased the range and rate of contraction and heightened the tonus of the diaphragm; large doses caused death by setting up powerful tonic contraction of the diaphragm with arrest of respiration, while the heart still beat strongly. This occurred when the vagi were divided, and therefore was due to action on the respiratory centre. An initial rise in blood pressure, with acceleration of the heart beat, was followed when the dose was increased by a fall of pressure. The strength of the heart's contraction was lessened. No effect on the vaso-motor system was noticed. Animals usually struggled, even after complete loss of corneal reflex, and regular rhythmic movements of the muscles of the limbs, tail, and jaws persisted; while muscular relaxation was seldom complete, even with large and dangerous doses. The pupil at first dilated, and subsequently contracted. Dr. Swan has examined the blood of patients before and after taking somnoform, and found no change in the amount of hæmoglobin, or in the number of leucocytes.

Now that these facts are established, it can hardly be wise to employ this mixture save under very exceptional circumstances.

* Introduced by Dr. G. Rolland in 1901 at the meeting at Ajaccio of the Congress of French Associations for the Advancement of Sciences (Odontological Section), and by him and Dr. Field Robinson at the Annual General Meeting of the British Dental Association at Shrewsbury, 1902. See *Brit. Dent. Assoc. Jour.*, 1902, p. 321.

† Proceedings of the Physiological Society, May 16, 1903, *Journal of Physiology*, vol. xxix. The reader should consult the paper by Dr. Adolf Haslebach, "Experimentelle Beobachtungen über die Nachwirkungen bei der Bromäthyl und Chloräthylnarkose," Bern, 1901.

‡ *Proceedings of Society of Anæsthetists*, vol. vi., 1903, p. 49.

§ *Op cit.*

The administration is conducted in a similar way to that of ethyl chloride, but the greater strength and danger of somnoform claim more caution and the closest attention to symptoms.

Phenomena of narcosis.—The face flushes as with ethyl chloride, the pink-red deepens almost to cyanosis if large doses are given, the respiration is quickened, but grows weaker and less full, and faint stertor is usually heard; the eyes become suffused and the eyeballs fixed in a position of deviation downwards and slightly inwards; more rarely the deviation is upwards; the pupils at first dilate, but later on, according to some observers, they become smaller. Dr. Kingsford, who has studied the changes of the pupil in 1,700 cases of somnoform anæsthesia, informs me he has never seen the pupil undergo contraction while the ocular globes remain fixed. After moderate doses the pulse is quickened, but is usually little altered in volume. If very full doses are administered, duskiness, distinct feebleness of breathing, with quick collapsing pulse result. Anæsthesia is present when the breathing is stertorous, and the mask should be removed—and in the case of children even if the conjunctival reflex is present, and the ocular globes are still moving. The depth of narcosis is increased for some seconds after the patient ceases to inhale; indeed in very young children the narcosis may continue to deepen for half a minute or even more, and this must be allowed for in determining the right moment for withdrawal of the anæsthetic.

After effects.—Much difference in the statements of those who have had large experience with somnoform exists as to the after effects produced by it. I think, however, that there is little doubt that nausea, vomiting, and severe headache are common sequelæ. The patients are commonly dazed for some minutes after the inhalation, more so than after ethyl chloride.

Difficulties and dangers.—Unless air is almost completely excluded, no anæsthesia will result. A mistake which results in failure is often made in keeping the mask too long on the face. If the signs of anæsthesia are not developed in 30 or 40 seconds, too much air has been allowed, or too small a dose has been given. When food has been taken within

a short time of the administration of the anæsthetic, pallor is likely to occur, followed by vomiting into the mask. Several cases have been reported in which severe collapse occurred, lasting for some hours and causing alarm. Mr. W. Foster Cross* mentions two cases in which marked general rigidity, opisthotonus, and spasm of the jaw muscles developed. And Dr. Swan† cites two cases of collapse, one in his own and one in the practice of Dr. Rolland. In both the patients had had anæsthesia prolonged by somnoform for twenty minutes. Excitement and struggling are occasionally met with. As Dr. Kirkpatrick‡ indicates, micturition is common if the bladder is not emptied before the administration, so this precaution should not be omitted. I have met with cases of excitement, but none of serious danger. Fatalities have occurred, however, during the use of somnoform; and when we bear in mind that Cole's experiments show conclusively that the physiological actions of somnoform and ethyl bromide are almost identical, it follows that the dangers of somnoform must be almost the same as those of ethyl bromide; and with these we must reckon. Somnoform readily decomposes; if any free bromide is present, the colour becomes yellow and the anæsthetic is unfit for inhalation. As a rule, the last portion in the bottle gives unsatisfactory results, especially if the bottle has been open for a day or so, and should not be used.

Ethyloform is a mixture of ethyl bromide, ethyl chloride, and methyl chloride, and would appear to be more dangerous than somnoform. Judging by the analogy of somnoform, however, it seems probable that the high percentage of ethyl bromide which it contains would dominate and give the mixture an identical action with this agent. It is exhibited in the same way as somnoform.

Narcotile,§ kelene, anæsthyle, and other anæsthetics which are sold under similar names are too uncertain in composition to require more than a passing notice. They are administered in the same way as ethyl chloride.

* *Proc. Soc. Anæsth.*, vol. vi. p. 45.

† *Ibid.*

‡ *Med. Press and Circ.*, April 22, 1903.

§ Dr. Tom Eastham, *Lancet*, April 18, 1903, p. 1091, gives his experience of narcotile, which he terms "bichloride of methyl ethylene."

Recently the presence of ethyl chloride in certain brands of chloroform has been noticed, and it is claimed that the more volatile agent renders the inhalation more rapid and more generally satisfactory. However, unless ethyl chloride is added in appreciable quantity—such, for example, as 3 per cent. or more—it is at least difficult to understand how its presence in chloroform can exert any marked action during the induction period.* We do not as yet possess sufficient evidence to come to any satisfactory conclusion as to the advantage of adding of ethyl chloride to chloroform. It is certain, however, that the mixture is more volatile than chloroform, and that during evaporation the composition of the mixture remains practically unaltered.

USES OF ETHYL CHLORIDE AND ITS MIXTURES.

For brief operations such as those of dentistry, the removal of tonsils and post-nasal adenoid growths, the opening of abscesses, and generally for occasions when nitrous oxide is commonly employed, ethyl chloride is useful. For brief operations upon infants and children under six years of age it is one of the best anæsthetics we possess, being more readily taken than ether when that agent is given by itself, easier to manage than nitrous oxide for very young children, and perhaps safer than chloroform. It is also a valuable means of introducing ether narcosis, and especially is this so in the case of nervous persons. Its use has been extolled in the operations of ophthalmology, and for those of the rhinologist, aurist, and laryngologist, when the time required by the surgeon is not more than two or three minutes. In the case of operations upon the eye, when after-vomiting is dangerous, ethyl chloride is less an ideal anæsthetic unless possibly when given by an open method.

For more prolonged operations upon the mouth and upper air passages, ethyl chloride as usually administered is inconvenient, since the surgeon is obliged to interrupt his work while the mask is reimposed and more anæsthetic is given. Dr. Barton† has obviated this by an apparatus which enables

* See Dr. Wade's paper in *Trans. Soc. Anæsth.*, vol. vii. p. 84.

† "A Guide to the Administration of Ethyl Chloride," p. 21, H. K. Lewis, London.

the anæsthetist to give the vapour of ethyl chloride continuously (see figs. 72 and 73). For this purpose the vapour is



FIG. 72.—Dr. Barton's apparatus for administering ethyl chloride for prolonged operations on the mouth or nose. Induction about to commence.



FIG. 73.—Anæsthetic being maintained by means of a tube.

carried by a tube either through the nostril or to a delivery-tube attached to a gag. The supply of vapour is maintained by the use of a specially constructed cylinder holding 250

grammes of ethyl chloride, which is controlled by taps. The vapour is warmed by hot water. In this way the narcosis can be maintained at the desired depth, and as long as is necessary.

A few words may be said as to the comparative merits of nitrous oxide gas and ethyl chloride, since these anæsthetics are used in similar cases.

Ethyl chloride is more portable; it does not produce cyanosis unless given for too long a time and with undue air limitation, and it ensures a deep and quiet period of anæsthesia, which is considerably longer than that obtained by the inhalation of nitrous oxide. On the other hand, it is certainly less safe, and is more liable to produce after-nausea and vomiting. In dental surgery I think ethyl chloride should not replace nitrous oxide as a routine anæsthetic, but may be adopted in the place of that gas when followed by ether, for cases of numerous or difficult extractions, *e.g.* of lower wisdom-teeth. For cases of multiple extractions in the upper jaw in persons with a short upper lip who are less easily kept anæsthetic by a continuous gas method, ethyl chloride is useful. For the removal of tonsils and growths in children, more especially in hospital practice, ethyl chloride is better than nitrous oxide; it is, indeed, considered by some as almost an ideal anæsthetic in these cases, especially when given by an open system.

Ethyl chloride may be strongly recommended for nasal operations, such as removal of spurs and portions of turbinate bones. It causes less congestion, and affords a quieter anæsthesia than the nitrous oxide ether sequence and one of at least equal length. It is safer than chloroform or its mixtures when given to patients in the sitting or recumbent posture. It may be used safely before cauterising the turbinate bodies.

Patients who are inclined to become cyanosed when inhaling nitrous oxide, and those who "come round" very quickly, and those who are restless and excited under that agent, usually respond well to ethyl chloride, and by its use a satisfactory anæsthesia can be obtained.

Ethyl bromide (hydrobromic ether).—Ethyl bromide, C_2H_5Br , is prepared by the action of phosphorous tribromide on alcohol. It occurs as a clear, colourless, heavy, strongly

refracting, neutral liquid, with a pleasant ethereal odour. Boiling point, $39^{\circ}\text{C}.$; specific gravity, 1.455.

It is soluble in water (about 1 in 100), and is freely soluble in ether and alcohol.

It is decomposed by exposure to air and sunlight, and should be stored in well-closed bottles in a dark place.

The principal tests are as follows:—

Residue.—10 c.c. evaporated in a shallow glass vessel on a water bath should leave no visible residue.

Free acid, bromine and bromides.—When 5 c.c. of ethyl bromide is shaken with 5 c.c. of distilled water, the upper aqueous layer should not redden blue paper, nor should it yield any turbidity on the addition of silver nitrate solution.

Ethyl bromide undergoes decomposition in the presence of air or light, with the liberation of free bromine, and becomes irrespirable. This impurity gives it a yellow colour, a circumstance which should warn against its use when at all tinted. Serullas discovered this substance in 1827, but to Nunneley of Leeds we are indebted for its recognition as an anæsthetic (1849).*

Physiological action.—Rabuteau, in 1876, carefully investigated the subject.† In human beings ethyl bromide produces unconsciousness and anæsthesia in one minute, and complete muscular relaxation in two or three minutes. Schneider speaks of two periods: in the initial one sensibility is lessened without loss of consciousness or interference with respiration and circulation; in the second there is complete loss of consciousness, occasionally with convulsive seizures. Larger doses produce profound narcosis, cyanosis, muscular relaxation, loss of pupillary reflex, and gradual failure of

* The late Sir B. W. Richardson wrote (*Asclepiad*, 1885) favourably of its claims, and urged that pure samples were free from the dangers which arise with the commercial bromide. The bibliography of "bromethyl" has become very large; important papers have been written by Hartmann and Bourbon (*Rev. de Chirurg.*, No. 9, 1893, p. 701), Dastre ("Des anesthetiques," p. 189, Paris, 1890), Lewis (*Medical Review*, New York, March, 1880, p. 342), Turnbull of Philadelphia, Chisholm, and Silk (*Practitioner*, May, 1891), among many others. A useful list of authorities will also be found in the valuable chapter on "bromethyl" in Terrier and Péraire's book ("Petit Manuel d'Anesthésie Chirurgicale," Paris, 1894, p. 154), to which the reader is referred for greater detail.

† *Comptes rendus de la Soc. de Biol.*, t. xxxiii. p. 1294.

respiration and circulation. The heart beats for an appreciable time after breathing has ceased. Elimination takes place by the lungs. No suffocation or laryngeal irritation appears to exist, although there is much congestion of the head and neck with lacrimation, and an increased secretion of mucus which may give trouble.

When ordinary doses are given to produce anæsthesia, the following phenomena occur: the breathing is quickened, the pulse accelerated, and the heart's action somewhat weakened. The pupils dilate. The return to consciousness after withdrawal of this anæsthetic is very rapid. Vomiting is said to occur frequently during the administration, and even to continue for some hours. Blood pressure, according to H. C. Wood, is slightly reduced by small, and very considerably by large, doses of this agent.

Deaths from ethyl bromide are due, according to Wolff and Lee, to cardiac failure; but these statements are denied by some observers. Ott, on the other hand, believes that ethyl bromide kills by direct action upon the respiratory centre, and does so whether it is injected intra-venously or is inhaled. The heart-failure, he thinks, is secondary to the interference with respiration. According to Ginsburg, this fall of blood pressure is due to paralysis of the vaso-motor centres, the vagus centres being unaffected. The action of this agent upon the heart is probably similar to that of chloroform (H. C. Wood). Tcherbacheff corroborates Wood's results, and asserts that death is caused by cardiac paralysis and pulmonary œdema. Cole was unable to detect any effect on the vaso-motor system; he agrees with Wood and others in believing that respiration is affected by the action of ethyl bromide upon the respiratory centre.

Method of administration.—In giving ethyl bromide, air is usually entirely excluded. Turnbull, however, allows some air at the commencement of the inhalation. An Ormsby's or an Allis's inhaler apparatus answers very well. When an Ormsby's inhaler is used, a drachm or a drachm and a half is poured upon the sponge, air being excluded until consciousness is lost (Silk). Anæsthesia is recognised by snoring and loss of conjunctival reflex. This usually occurs in half a minute to a minute, and at this point the inhalation

must be stopped. Although it is asserted by some observers that there is little struggling, violent movements certainly take place in some instances. Owing to the great rapidity with which consciousness returns (1 to 3 minutes), careful attention is needed on the part of the anæsthetist to maintain narcosis. The respiration and pulse require watching throughout the administration. No prolonged operation should be attempted under ethyl bromide; even when it is given intermittently authorities agree that the inhalation should not be continued beyond forty minutes. It is, however, best adapted for quite short operations.

Hartmann and Bourbon adopt the following plan: 10 c.c. to 15 c.c. (2-4 drachms) are placed on a compress, and as soon as the patient grows used to the odour the compress is placed tightly over the mouth and nose. If any struggling occurs, the patient is held in the recumbent posture for a few seconds, when he becomes quiet. Anæsthesia supervenes after a dozen breaths, *i.e.* in about 30 or 40 seconds. Inhalation must now cease, or severe muscular convulsions become developed. When an operation cannot be completed in about one to two minutes, one or two inhalations of the concentrated vapour are given; then air is admitted, to be followed, if necessary, by further inhalations of the anæsthetic. It seems, however, wiser to give only one dose, and to follow it by ether. One to two drachms is a safer dose.

Terrier adopts the following method: A few drops are poured on at a time, all air being excluded, and more ethyl bromide is added guttatim when the last dose has evaporated. When air-exclusion is not practised, this anæsthetic can be exhibited from a Skinner's or other mask. In this method a considerable quantity of the anæsthetic is used. Turnbull, who was one of the first to employ ethyl bromide and to study its action, uses a towel folded into a cone. He pours into the cone 75 to 150 drops in the case of an adult, and 50 to 100 in that of a child. Kocher of Berne, according to Dr. Huggard,* employs this agent before ether. He suggests 15 to 30 c.c. (4 to 6 drachms) at a time as one dose. As soon as the signs of narcosis appear ether is substituted. Very weak or anæmic people and young children are

* *Lancet*, Sept. 12, 1903, p. 745.

considered by Kocher[]] to be bad subjects for this method. Alcoholism and Bright's disease are contra-indications to its use.

Cases suitable for ethyl bromide.—At the present time few persons employ this anæsthetic. If used at all its use should be restricted to brief operations, *e.g.* in dentistry, but it seems unwise to adopt so potent a drug for this class of operations. Turnbull has employed it in midwifery.

Dangers resulting from the use of ethyl bromide.—Eight deaths at least are stated to have resulted from its administration, but some of these were in reality due to impurities contained in the sample used. Deaths have occurred, however, when the pure drug has been used; so I am disposed to agree with Professor Wood,* who regards this agent as equally dangerous with chloroform. Cases of death due to inhalation of ethyl bromide have been recorded in which visceral degenerations were noted (Reich and Flatten). A. B. Kelly,† who has used this agent extensively, had thirty samples examined, and 60 per cent. were found to be unfit for anæsthetic purposes. The importance of obtaining absolutely pure specimens cannot be over-estimated. Even pure ethyl bromide, however, rapidly deteriorates when exposed to light, and must then be discarded.

Pental.—Trimethylethylene was described by Von Mering as an anæsthetic in 1887, and has been widely used in Germany for brief operations. Amylene, an agent which was employed with some success by Snow in 1856, agrees in many of its physical and chemical properties with pental. It is not now used.

Administration.—Pental is given with the same precautions as in the case of chloroform. Holländer‡ employed Junker's inhaler in its exhibition. Mr. Constant, of Scarborough, has used pental in dental surgery, exhibiting it from a Clover's regulating ether inhaler. Dr. Stallard, of Manchester, has used pental in 150 cases; he also adopts Clover's

* *Therapeutics*, 1905, p. 102.

† *Brit. Med. Jour.*, Aug. 30, 1902.

‡ Holländer's "Pentalnarkosen, 1893," in *Deutsch. Med. Woch.*, No. 33, contains much information on pental, and should be referred to for further details.

inhaler, pouring in two drachms and excluding all air until unconsciousness is obtained. The lid reflex was only lost in deep narcosis. The breathing under pental becomes almost imperceptible; cyanosis and stertor are rare. The induction period is about 57 seconds, and the anæsthesia lasts 76 seconds.

After effects.—Muscular contractions, enfeeblement of the heart-action, and respiratory spasm were noted. Dr. Stallard has met with one fatal case. The dangers of pental are summarised by this observer: (1) Its insidious action renders it very difficult to avoid giving an over-dose; (2) tendency to make the patient scream; (3) tendency to respiratory failure; (4) causes cardiac failure. Breuer (Vienna) had one threatened death from respiratory failure in 120 cases. He found the anæsthesia too slight for the reduction of dislocations. Both Schede* (Hamburg) and Sick† have noted casualties under pental. According to Kleindeinst, albuminuria, hæmaturia, and hæmoglobinuria may follow its inhalation. Cerna found marked fall of arterial pressure ensued upon its inhalation, while Gurlt's statistics gave pental a death-rate of three fatalities in 600 narcoses. In spite of these alarming statements, we find Philip,‡ from his experience in the Kaiser Friedrich Children's Hospital, Berlin, strongly in favour of pental. He met with no serious after effects.

The advantages claimed for pental over other anæsthetics appear to be more than counterbalanced by its dangers, which seem to depend upon the drug itself, and not upon any faulty method employed. At best it is only of use in short operations, and only when a superficial narcosis is required.

* "Congress der deutsch. Gesellschaft f. Chir. zu Berlin," *Berlin. klinische Woch.*, Aug. 1, 1892, p. 784.

† *Deutsch. Med. Woch.*, No. 20, 1893, p. 486, and No. 22, p. 538.

‡ *Zeitsch. f. Kinderheilk.*, Bd. iii., iv. 1893.

CHAPTER VII.

ALKALOIDAL DRUGS WITH GENERAL OR LOCAL ANALGESICS: ANÆSTHETIC MIXTURES, SUCCESSIONS, AND SOLUTIONS.

I. THE EMPLOYMENT OF ALKALOIDAL DRUGS ANTECEDENTLY TO GENERAL OR SPINAL ANÆSTHESIA OR LOCAL ANALGESIA.

ALTHOUGH morphine alone or with atropine has been used for many years, the systematic employment of the alkaloids in anæsthesia has only recently gained acceptance. The ends subserved are : (1) The patient is soothed if not completely put to sleep before having a general anæsthetic, or a local or spinal analgesic, administered.; and so is spared the distress often felt by nervous persons ; (2) the amount of the general anæsthetic required is diminished ; (3) many of the undesirable effects incidental to general anæsthesia are prevented, *e.g.* the salivation and bronchorrhœa caused by ether do not arise if atropine has been previously injected ; (4) psychic shock, which, according to Dr. Crile, acts so prejudicially upon the central nervous system, is lessened or abrogated.

The attempt to obtain complete anæsthesia by alkaloids has not been found successful in general surgery, or perhaps it should be said has not been found to be so efficacious as the combined use of these drugs with general or local agents. The elaborate method due to Gauss still finds advocates when it is restricted to obstetric practice, and reference to it will be found in the section dealing with that subject on page 373.

The experience of the last thirteen years, that is, since Schneiderlin, availing himself of the discovery of scopolamine by Schmidt (1890), has shown that the three drugs, scopolamine, morphine, and atropine,* when used together, give a better result than when they are used in other combination. They appear to supplement one another's actions in some directions acting synergistically, but to antagonise each other in other directions, thus protecting the patient from deleterious consequences. This is brought out in studying the development of the use of some alkaloids. Thus Nussbaum, of Munich, suggested the use of **chloroform** and **morphine** as early as 1863; Claude Bernard studied the combination in 1863; while MM. Guyon and Labbé, employing gr. $\frac{1}{8}$ to gr. $\frac{1}{2}$ of morphine, applied this method in surgery. Although Kappeler stated that the heart is protected by the use of morphine the consensus of opinion is opposed to this view, and there is no doubt, as Dastre has pointed out, that it depresses the respiratory centre. As Sir Victor Horsley has shown, the danger of respiratory collapse is increased when morphine is employed for patients whose respiratory centres are affected by disease. Poncet, from his experience in the Franco-Prussian War, came to the conclusion that this combination is dangerous both on account of the prolonged stupor it engenders, and because it causes a lowering of body temperature. Demarquay's experiments on animals also support this view. Further, according to Regnier, the elimination of chloroform is delayed by the preliminary injection of morphine.

It is, however, highly probable that many of the dangers attributed to this method are in fact the result of a failure to recognise that when morphine has been used, even in small doses, the quantity of chloroform subsequently given must be materially lessened. If this is not done the cumulative effect of these two powerful drugs upon the respiratory centre will undoubtedly predispose to collapse and death from

* See a clinical lecture by the present writer, *Clinical Journ.*, June 14, 1911, p. 145, for further information. Dr. W. Webster (*Bio-Chem. Journ.*, vol. iii., no. 3) describes a series of experiments on these alkaloids. His views vary in some regard with those expressed in the above account, but the conditions of his experiments are not quite parallel to those obtaining in clinical work.

asphyxia. To counteract some of these dangers, Dastre, Morat, Aubert (Lyons), and others introduced the plan of using a **morphine** and **atropine** injection antecedently to chloroform. The method of giving morphine gr. $\frac{1}{8}$ and atropine gr. $\frac{1}{160}$ to gr. $\frac{1}{80}$ has been widely employed, and many anæsthetists still adopt it. The drugs are injected one hour before the general anæsthetic is introduced. Dr. McCardie, however, thinks that the injection should be made three to four hours before the operation in order that the full morphine effect may be present at the commencement, and be practically exhausted before the operation is completed.

To Julliard, of Geneva, we owe the combination method of **morphine** before **ether**, but as a result of experiment and clinical observation it has become abundantly evident that any of the general anæsthetics in use may be given with advantage in association with a preliminary injection of alkaloids.

When no somnifacient effect is desired **atropine** in doses of gr. $\frac{1}{160}$ to gr. $\frac{1}{80}$ may be employed to exert its antagonising influence. Thus Sir E. Schäfer has demonstrated that this alkaloid lessens **vagal activity** and he recommends its employment to prevent the danger of **vagal inhibition** of the heart when chloroform is inhaled. He suggests that as much as gr. $\frac{1}{80}$ may be used in suitable cases, but it must be remembered that atropine when given alone often causes a disagreeable dryness of the mouth and throat which may persist for some hours.

The various objections to morphine which have been noted above are due, it is believed by some observers, to the impurity of the drug, or at least to the differences of strength which exist in the drugs employed. Dr. Sahli, of Bern, believing that it is possible to obtain standardised solutions of the chlorides of opium, has combined under the trade-name of **Omnopon**, a mixture of the chlorides of the following : * morphine, narcotine, codeine, papaverine, narceine, thebaine, hydrocotarnine, codamine, laudanine, laudanidine, laudanosine, meconidine, papaveramine, protopine, lanthopine, cryptopine, gnoscopine, oxynarcotine, xanthaline, and tritopine. It is an

* See a careful review of this subject by Dr. C. L. Leipoldt, F.R.C.S., entitled "Some Remarks on Omnopon Anæsthesia," *Lancet*, Feb 11, 1911.

amorphous yellow-brown powder, soluble in water, stable and with a slight acid reaction. One gramme of omnopon equals five grammes of 10 per cent. opium, but this estimate Dr. Leipoldt regards as too low. The same authority states that it is safer than the scopolamorphine (scopolamine and morphine) injection, producing less excitement and greater quietude. The dose is 1 c.cm. of a 2 per cent. solution; this is injected one hour before the operation, although dividing the dose and giving two or three injections at $1\frac{1}{2}$, 1, and $\frac{1}{2}$ hour before the inhalation gives a better result. It may be combined with atropine and possibly with scopolamine.

TECHNIQUE IN THE USE OF SCOPOLAMINE, MORPHINE (OMNOPON), AND ATROPINE.

It is to be remembered that the ordinary rules guiding the clinical use of morphine, atropine and scopolamine must be followed in this method, with the reservation, however, that the respiratory mechanism is less affected when all the three drugs are used together than if morphine and atropine alone are introduced. It is sometimes urged that since scopolamine and atropine possess common properties there is no advantage in employing the former. This is, however, a mistake, for scopolamine acts not only as one of the atropine group, but is a useful somnofacient, and my experience, which is now an extended one, convinces me that better results follow the use of the combination of all three drugs. It is also advanced as an objection to the method that the post-operative sleep is very profound and very prolonged. This is so after long and exhausting operations, but therein lies one of the greatest advantages of the method. It is true that the patient needs closer watching for some hours during his recovery than when only a general anæsthetic is used. This, although possibly an objection in large general hospitals which are understaffed with nurses, should not weigh in private practice. It is essential that chin drop should be looked for and at once corrected and that the posture of the patient be carefully arranged so that no postural interference with respiration, however slight, can arise. The nurse must, of course, be warned upon these points. Again, since the drugging of the

patient is already tolerably deep the amount of the general anæsthetic given to him after induction is complete should be extremely small. Assuming that these preliminary considerations have received due attention we may indicate the appropriate procedure. This applies to all cases when a general anæsthetic is to be given either by inhalation, intra-tracheal insufflation, intra-venous infusion, colonic absorption, or a local, regional infiltration, or spinal anæsthesia is to be practised.

If **hedonal** or **isopral** infusion is contemplated the preliminary injection should **not** be given.

The patient should be placed upon a wheeling trolley in his own room well covered up, and a hypodermic injection of the following solution—scopolamine gr. $\frac{1}{100}$, morphine gr. $\frac{1}{8}$, or an equivalent dose of omnopon,* and atropine gr. $\frac{1}{100}$ —should be given into a sterilised area of his arm. It is best to keep the preparation in ampoules which are sterilised and sealed. An ampoule is broken and the fluid taken into the syringe, but care must be used that only five minims—the amount of fluid holding the doses given above—is drawn into the syringe. It is impossible to ensure that any given ampoule contains only this amount. The dose may be given one hour or one hour and a half before the operation, or in two doses, one two hours, the other one hour before. In the case of very vigorous males more than gr. $\frac{1}{8}$ of morphine may be required, and if this is so it is better to divide the dose, giving first morphine and subsequently the three drugs. As delicate persons and children may require a smaller dose, such variations in dosage should be decided in each case on general grounds. It is unwise to increase the dose of scopolamine given. *After the injection the patient should be kept absolutely quiet*, no talking or movement must be allowed, and the room must be darkened. If ether is to be employed, it is better to give a few whiffs of chloroform to deepen the “dawning sleep” before ether is administered, as its pungent smell arouses the patient. Personally, I do this with a Vernon Harcourt inhaler. On no account must the patient be allowed to walk to the operating-room—indeed, it

* Supplied by the firm of Hoffer mann, La Roche, who prepare it in sterilised ampoules.

is best to anæsthetise him in his own room and then wheel the trolley into the operating-room and carefully slide him on to the operating-table from the trolley.

Subsequently the anæsthesia is pursued along normal lines provided the caution given above is not lost sight of, *i.e.* that the patient will need extremely little of any anæsthetic to maintain unconsciousness. It is quite a common occurrence for the patient to move a leg when the first skin incision is made, but he does not repeat this. The breathing is usually slow and the lung ventilation slight, so that the induction period is sometimes rather prolonged. The signs of anæsthesia are somewhat masked. The ocular phenomena are not reliable as the pupillary reaction is altered by the drugs, and conjunctival reflex is lessened in the same way, but is seldom absent, nor should it be during the operation. As has been stated above, the period of recovery is long and the patient requires watching. The after effects, sickness, headache, etc., are materially lessened.

Some surgeons consider that muscular rigidity is increased by the use of scopolamine, but this, I think, is not the case. If the abdominal muscles are stiff it is usually due to ineffectual breathing and the associated signs of slight asphyxia, of which muscular rigidity is one.

When **ether** is to be given alone, even if morphine and scopolamine are not used, the injection of **atropine** should never be omitted. It prevents excessive secretion of mucus and of saliva, and so removes the most potent cause of after-sickness, and post-anæsthetic lung complications. Although one hour is the best interval of time which should elapse between the hypodermic injection and the giving of the anæsthetic, yet if for any reason this arrangement is impossible, the injection may be given later; especially is this so in the case of atropine.

If scopolamorphine or morphine alone is injected not long before the use of the anæsthetic the anæsthetist must be prepared for a gradual increasing opium effect which will probably be at its height at the time that the operation is completed.

Comparing the post-operative condition of patients treated in the above way with those who have not had the

hypodermic medication, that of the former class is remarkably better than that of the latter.

If there is any necessity for a speedy induction the routine system mentioned above of nitrous oxide—ether (by closed method) followed by open ether or chloroform, lends itself admirably for the anæsthesia subsequent to the hypodermic injection.

II. ANÆSTHETIC MIXTURES, SUCCESSIONS, AND SOLUTIONS.

The rationale of using mixtures involves two principles. The one is that in these mixtures chloroform is diluted. It is assumed that the constituents of a mixture evaporate in a definite proportion to their strength in it. If A, B, C, were a mixture such that one part of A were combined with two parts of B and three of C, it is assumed that the vapours of A, B, and C would be represented by the proportions of 1, 2, and 3. The other principle involved is that it is possible by combining two or more anæsthetics in a mixture to induce mutual antagonism in certain directions, thus producing a resultant action which protects the patient from the deleterious effects of the individual constituents of the mixture. After the acceptance in France and throughout Europe of Bert's pronouncement that the danger of chloroform is merely a question of the concentration of the vapour inhaled, a number of methods were suggested with the object of obtaining a dosimetric system of giving chloroform, and among these were various mixtures schemed with the view of keeping the chloroform constituent below 2 per cent.

Mixtures.

These are of two classes : (1) Combinations of the alcohol or ethereal series ; (2) Alcoholic or anæsthetics used in conjunction with other agents.

The best known and most useful of the first class are :—

The A.C.E. MIXTURE.—Composed of 1 part absolute alcohol, 2 parts chloroform, and 3 parts of ether, all by volume.

The C.E. MIXTURE.—Compound of 2 parts by volume of chloroform, and 3 parts by volume ether.

BILLROTH'S MIXTURE.—3 parts by volume of chloroform, 1 part by volume each of absolute alcohol and ether.

The VIENNA MIXTURE.—1 part by weight of chloroform to 3 parts by weight of ether. Richardson* gives the formula for this mixture as 8 parts of ether to one of chloroform in hot weather, and 6 parts of ether to 2 of chloroform in cold.

The MIXTURE recommended by Linhart.—1 part by weight of absolute alcohol, 4 parts by weight of chloroform.

Sir E. Schäfer advocates a MIXTURE of 1 part by volume of absolute alcohol and 9 parts by volume of chloroform.

"METHYLENE."—Methylic alcohol 30 per cent. and 70 per cent. chloroform by weight (Regnaud and Villejean).

SCHLEICH'S SOLUTIONS:—

	No. 1.	No. 2.	No. 3.
Chloroform . . .	45 parts.	45 parts.	30 parts.
Sulphuric ether . .	180 "	150 "	80 "
Petroleum ether . .	15 "	15 "	15 "

The A.C.E. mixture was suggested by Dr. George Harley, and strongly recommended by the Anæsthetics Committee of the Royal Medical and Chirurgical Society of London. They speak of its action as midway between that of chloroform and ether. It is made by mixing one fluid ounce of absolute alcohol sp. gr. 0.795 with two fluid ounces of chloroform sp. gr. 1.497 and three fluid ounces of ether sp. gr. 0.720. It has been largely used in England, and, although not without objections, is a good substitute in many cases when ether cannot be taken. The main drawback to the employment of this and all other mixtures is that the agents employed in their formation do not evaporate in the ratio in which the fluids are mixed, and hence it is impossible to be quite sure what percentage vapour of chloroform is being inhaled. The liability to this irregular evaporation may be minimised by evaporating one drachm or a half-drachm of the mixture at a time. When used in these small quantities the evaporation discrepancy is of less importance.

* *Asclepiad*, 1885, p. 274.

To obviate this difficulty, Ellis* proposed to blend the vapours of alcohol, chloroform, and ether in a specially constructed apparatus, with the view of obtaining a combination of vapours of the constituents corresponding with the proportion in which the fluids are blended. The arrangement he used is too complicated for practical purposes, and his method has never been received with much favour. Dr. Gwathmey† has revived Ellis' suggestion and has invented a practical apparatus. This consists of three six-ounce bottles, in each of which are four tubes varying in length from one which reaches the bottom of the bottle to one which only perforates the stopper. These tubes are assumed to represent four vapour strengths. Air or oxygen is forced through these tubes by means of a hand-pressure ball—as in Junker's apparatus—and the amount is assumed to be determined by the degree of compressure exercised. Dr. Gwathmey's most recent apparatus obviates some of the sources of error common to such inhalers. A somewhat similar idea is carried out by Tyrrell's double-bottle method. The vapours of ether and chloroform are made to enter a common face-piece by an arrangement whereby two Junker's apparatus are made to pump the vapours through the tubes (see below).

Method of employment.—This anæsthetic mixture may be given in a Rendle's mask, a cone, or by the open method. When a cone or Rendle's mask is used, a drachm of the mixture is poured into the mask, and fresh quantities added when the first has evaporated. I find Allis' inhaler also answers well. Junker's inhaler, fitted with the flannel mask, is very convenient for giving the A.C.E. mixture to children. With the open method, much ether vapour escapes into the surrounding air, and the induction period is longer. In the case of children and very nervous persons it is a good plan to give the A.C.E. mixture guttatim on a mask or corner of a towel, replacing it by the inhaler when the patient has become unconscious. Although this solution is sometimes given from a "Clover's" inhaler, the bag having been taken off, the method is, I think, not free from danger even if the

* *Med. Times and Gas.*, 1870, vol. ii., p. 107.

† *Med. Record* (New York), Oct. 14, 1905.

inhaler is constantly lifted from the face and air very freely admitted.* The fact that chloroform is present in the mixture makes it obligatory that plenty of air be allowed the patient, to effect which the cone or inhaler should frequently be raised from his face. Both respiration and pulse must be carefully noted, as fainting and asphyxial troubles may occur during the employment of the A.C.E. mixture. The signs of anæsthesia are those described when dealing with chloroform in the preceding chapter. Duskiness is common and is due to insufficient air. Stertor should never be permitted. Patients who will not tolerate ether often take A.C.E. well.

After effects are much the same as those of chloroform or ether, although they are commonly slight. Deaths have occurred during the use of the A.C.E. mixture, and have been attributed both to respiratory and cardiac failure. Physiologically the A.C.E. solution resembles chloroform antagonised to some extent by the alcohol it contains. This antagonism reveals itself in the maintenance of the height of blood pressure, and in keeping the respirations at a force and frequency very little below normal.

The **C.E. mixture** is simply the A.C.E. solution with the omission of the alcohol. In the Report of the Royal Medico-Chirurgical Society issued in 1864, three mixtures are given : (A) the A.C.E. (George Harley), (B) chloroform one part and ether four parts by volume, and (C) chloroform one part and ether two parts by volume. (B) and (C) are there stated to have been used extensively in America (*sic*). The action of (B) is said to resemble that of ether, and this is true during the earlier part of the administration, since the ether evaporates more rapidly than does the chloroform. The C.E. mixture is in common use and is prepared by mixing two parts of chloroform (by volume) with three parts of ether (by volume). It is employed in the same way as the A.C.E., over which it possesses no advantage.

* See a valuable paper by Dr. Edgar Truman, *Lancet*, Feb. 16, 1895, p. 403, and a further one on the same subject by Sir William Ramsay, F.R.S., *Transactions of Society of Anæsthetists*, vol. ii., p. 13, in which it is pointed out that this mixture, given from a closed inhaler, is unsafe on account of the irregular manner in which the constituent parts are given off, even when the bag is removed, owing to the respective densities of the vapours ; the chloroform falls while the ether evaporates into the room.

The research of Schäfer and Scharlieb * shows conclusively that the C.E. mixture is based upon a wholly fallacious theory that the alcohol in the A.C.E. mixture is merely a menstruum, and the ether in the C.E. mixture exerts a stimulant action upon the circulation, and so counteracts the depressant effect of the chloroform contained in the mixture. They prove that the C.E. mixture acts precisely like chloroform of similar strength, that the ether exercises no independent action—is, in fact, a mere diluent. Nor is this all. They found, further, that the A.C.E. mixture owed its undoubted merit wholly and solely to its alcohol (16·5 per cent.), while its ether was, as far as blood pressure went, a negligible quantity. The proportion of ten parts by volume of absolute alcohol to ninety parts by volume of chloroform in their hands gave better results than did the larger amounts of alcohol. In fine, their results indicate that the C.E. mixture is more dangerous than the A.C.E., is about upon a level with diluted chloroform, and when employed without complete admixture with air is to be avoided; that the A.C.E. mixture possesses no advantage over the alcohol-chloroform mixture (1 in 10), and should be replaced by it. These remarks apply with equal force to **Richardson's mixture** (alcohol 2, chloroform 2, and ether 3 parts) and the **Vienna mixture** (chloroform 1, ether 3 parts).

Billroth's mixture (alcohol 1, ether 1, chloroform 3 parts) may be considered as an alcohol-chloroform mixture of 20 per cent. alcohol which, from what has been said above, possesses no advantages over the 1 in 10 mixture. If used at all it must be given in the same way as diluted chloroform, and with the same precautions.

Tyrrell † employs the **apparatus** depicted below to effect the **commingling** of air impregnated with the **vapour** of **chloroform** and that of **ether**. The tubes are so arranged that the administrator can give as much of each vapour as he decides is required for the case. One pair of bellows controls the two bottles, a Y-shaped piece with a little graduated tap on each bifurcation of the Y being inserted between, while a similar Y-shaped piece allows the passage of the vapour

* *Trans. Roy. Soc. Edin.*, vol. xli., part ii., no. 12.

† *Trans. Soc. Anesth.*, vol. i., p. 1, 1898.

from each bottle to a single tube which is attached to the face-piece. Before commencing the inhalation the tap controlling the ether supply is adjusted so that only so much ether will escape as can be respired easily. In the case of a child less ether is allowed to pass. This tap is left in this position, but the tap on the bottle cutting off the ether is closed, and only opened if in the course of the administration of the chloroform, conducted on ordinary principles, ether is



FIG. 74.—Tyrrell's method of combining the vapours of chloroform and ether.

required. The same end has been obtained by various apparatus which, although possessing merit, cannot be described in this place.

THE ROTH DRAGER CHLOROFORM AND ETHER APPARATUS.

This is one of the best systems in that it supplies the anæsthetist with a ready means of giving either chloroform or ether or a combination of these in definite doses and in association with oxygen.

Oxygen under pressure is passed into a bag taking up the vapour of chloroform and ether as the latter is to be used. These anæsthetics drop at definite rates controlled by a

simple mechanism. The pressure of oxygen, which is lowered to 5 kgm., and the rate of dropping of the anæsthetics per minute are registered on dials. The mixed vapours and oxygen enter a special type of metal valved face-piece, which is supplied with an air slot admitting the required proportion of air. The actual percentage vapour is readily estimated, and the strength used is under the control of the anæsthetist. I have used the apparatus and found it quite reliable. The only objection to it for general use is that higher percentages of CHCl_3 vapour than 2 are easily obtained and this fact probably accounts for the fatalities which have occurred during its use.

Alcohol-chloroform mixtures.—Schäfer and Scharlieb* have shown the superiority of these over mixtures containing ether. The 1 in 10 mixture is administered in the same way as pure chloroform, and with the same precautions. This mixture is conveniently termed the "A.C." mixture.

Linhart's mixture (20 per cent. alcohol) is employed similarly. It contains more alcohol than is necessary, and gives less good results than the 10 per cent. mixture.

Methylene, or "bichloride of methylene," is stated by Regnault and Villejean to be merely a mixture of methyl alcohol (30 per cent.) and chloroform (70 per cent.). It is seldom used at the present time. It may be given from a Junker's inhaler. It is inferior to the above-mentioned alcohol-chloroform mixture, and is less safe. Several deaths have occurred during its use.

Schleich's solutions for general anæsthesia.—The rationale of these solutions lies in the assumption that the rapidity with which anæsthesia can be obtained and the permanence of the anæsthesia depend upon the boiling point, or temperature of maximum evaporation of the agent which is inhaled. It is assumed that by altering the temperature of maximum evaporation, so as to make it nearly coincide with the blood heat, it would be possible to regulate the intake and elimination of the anæsthetic vapour in such a manner as to maintain anæsthesia without over-narcotism, since the elimination under such conditions would prevent accumulation of the anæsthetic in the blood. Schleich

* *Op. cit.*

proposes three solutions : No. 1 for light, No. 2 for medium, and No. 3 for deep anæsthesia. These are :—

	No. 1.	No. 2.	No. 3.
Chloroform . . .	45 parts.	45 parts.	30 parts.
Ether (sulphuric) 180 "	180 "	150 "	80 "
Ether (petroleum) 15 "	15 "	15 "	15 "
Boiling point .	38° C.	40° C.	42° C.

The petroleum ether employed must have a boiling point between 60° and 65° C., and a sp. gr. between '670 and '700, since the common commercial kind induces deleterious effects when inhaled for any time. Willie Meyer (New York) and Maduro (New York) have employed the solutions, and were favourably impressed by them, but their experience does not seem to have been that of others who have employed these solutions.

According to Rodman,* the induction of anæsthesia took from fifteen to twenty minutes. The solution, although causing some excitement, compared favourably with ether in this respect, and also produced more complete muscular relaxation. There was also less irritation of the mucous membranes. The early disappearance—presumably before true anæsthesia—of the reflexes, especially the ocular, is, he thinks, a drawback, as the anæsthetist loses a valuable guide. The patients, after inhaling No. 3 solution, became cyanosed, the pulse slowed and grew weak, the pupils were dilated, while the respirations were shallow and rapid. Eventually the cyanosis became general, the breathing infrequent and feeble, and, with little warning, stopped altogether. This occurred in six cases which he witnessed, while in others profound circulatory depression, with heart failure, was seen. Retching and vomiting were, Rodman contends, as frequent as with other anæsthetics, nor was the return to consciousness more rapid or freer from inconvenience. Schleich appears to regard the recovery as like that of one awakening from slumber. Upon the lungs and kidneys the effects were much the same as with ether. Bronchitis, followed by pneumonia, occurred in several cases, being in some instances fatal. Rhinitis and conjunctivitis were observed as sequelæ, and

* *Med. Rec.* (New York), Oct. 1, 1898.

in three antecedently healthy persons albuminuria with casts in the urine, followed the inhalation of the solution. Rodman further records a case in which heart failure of the most pronounced nature resulted from inhalation of No. 3 solution.* It would appear that after a somewhat extensive trial of Schleich's solutions their use has become very much restricted.

Wertheim's solution (1 part chloroform, 1 part petroleum ether, and 2 parts sulphuric ether) has been used in this country by Dr. Probyn Williams.† It was administered from a mask—a modified form of Skinner's frame—and the experience gained from a limited number of cases is said to be favourable. Dr. Silk's‡ experience of Wertheim's solution has led him to believe that the petroleum ether which it contains is inoperative, so that the solution is practically one of sulphuric ether and chloroform. As such he considers it has some merits.

Chloroform and ether in various combinations and sequences.—A great variety of combinations and successions of these, besides those mentioned above, have been proposed from time to time, but need no special mention. (See chapters on Ether and Chloroform.) One point, however, must again be dwelt upon, and that is that either in the case of chloroform given before ether, or *vice versa*, great care and watchfulness must be employed, since in the one case the reaction from circulatory depression to circulatory stimulation, and in the other from circulatory stimulation to vaso-motor depression, may produce bad effects and even lead to accidents. Professor Julliard§ regards the plan as one "combining the dangers of chloroform with the inconveniences of ether."

A.C.E. mixture followed by ether or chloroform.—See articles on A.C.E. Mixture, Ether, and Chloroform, respectively.

* See an article in *Year Book of Treatment*, 1899, p. 177.

† *Transactions of Soc. Anæsth.*, vol. iv., p. 98: "A note on a modified form of Schleich anæsthetic mixture by R. J. Probyn Williams, M.D., Harold Barnard, M.S., and Russell Howard, M.B."

‡ *Transactions of Soc. Anæsth.*, vol. v., p. 138.

§ "L'éther est il préférable au Chloroforme," *Rev. Med. de la Suisse Romand.*, Feb. 1891.

Nitrous oxide and ether.—This combination is fully described under "Ether," p. 169. It is the best method of producing general anæsthesia. When complete unconsciousness has been attained by giving nitrous oxide, the duration may be prolonged by allowing the gas to pass through the ether; or, by turning off the gas altogether, the patient may be kept anæsthetised by ether for a lengthened period. The objection urged by Terrier and Péraire that the vapours are liable to explode is, I think, purely theoretical, or unless through gross carelessness the mixture is allowed to become strongly heated.

Clover's gas and ether apparatus enables one to regulate the supply of gas or ether with a nicety and precision unattained by any other instrument. When chloroform is not given by means of an accurate regulating inhaler, it is an excellent and safe plan to induce anæsthesia by the nitrous oxide and ether succession and maintain it by means of chloroform. As has been pointed out above, this sequence can be advantageously employed for the induction of anæsthesia even when it is desired to use the open ether method throughout the anæsthesia. The precautions and dangers incident to this method are those fully described in the chapters upon Nitrous Oxide Gas and Ether.

The ethyl chloride and ether sequence is described on page 174. It is an alternative to the nitrous oxide-ether method.

Ethyl bromide and chloroform.—The employment of these drugs *in succession*, similarly to nitrous oxide before ether, is, according to Terrier and Péraire, extremely useful. Otis (Boston) has suggested ethyl bromide 1 part, chloroform 3 parts, and alcohol 4 parts, and has employed it extensively in general and obstetric surgery.

Ethyl bromide followed by ether.—This method is advocated by Kocher of Bern.

Chloroform vapour with oxygen.—This obvious combination was employed very early in the history of the anæsthetic. It has more recently been revived by Neudörfer and others. I have made many experiments with this combination, and although I cannot find any true physiological antagonism between chloroform and oxygen, such as is

asserted by some, there is no doubt in my mind that for persons with a tendency to become cyanosed or congested, the employment of oxygen with chloroform is most useful. I have used the oxygen *pari passu* with the chloroform without attempting a definite percentage dilution. Neudörfer employs 10 per cent. by the use of a special apparatus. A special apparatus is not, however, necessary. It is extremely simple, by connecting the oxygen supply bottle with a nasal or mouth tube, to give as much or as little of the gas as the patient requires. Kreutzmann makes use of Junker's apparatus, pumping oxygen instead of air through the supply tube. There is, however, a danger in this proceeding. The supply of oxygen to the patient prevents the appearance of cyanosis, and chloroform may be pushed until the respirations stop through over-dosing the respiratory centre. When the Vernon Harcourt chloroform inhaler is in use, oxygen can be advantageously given by connecting the supply to a special tap fitted to the stem of the inhaler. The oxygen should be warmed by passing it through a tube immersed in hot water, whenever this is possible.

The value of oxygen given with chloroform consists in obviating any intercurrent asphyxial condition, causing rigidity, cyanosis, and impaired breathing. It does not antagonise the action of chloroform on the heart or nerve centres, although it protects the patient from the double dangers which arise when chloroform is inhaled while his blood is in a condition of undue venosity. The chloroform, although still able to act prejudicially upon the tissues, is less powerful when they are well oxygenated. It must not be forgotten, however, that over-dosage is as liable to occur with as without oxygen.

Chloroform and chloral.—The preliminary giving of chloral was first employed at the Hôtel Dieu by Dubois.*

Perrin used as large a dose of chloral as gr. 45 for adults, given one hour before giving chloroform.

Dastre gives 2 to 5 grammes of chloral an hour before administering the chloroform by inhalation.† He explains the action of the agents thus: the chloral, acting as an

* "Anesthésie Physiologique," par Dr. R. Dubois, 1894, p. 135.

† "Les Anesthésiques," p. 249.

hypnotic, composes the patient to sleep, and the tranquillity and lethargy of the patient enable the administrator to maintain true anæsthesia by the use of a small quantity of chloroform. The plan has been fully tried by Dolbeau, Guyon, and others, and they find the patients remain cold, faint, and collapsed for hours after the inhalation, and are peculiarly liable to bleeding, owing to the relaxation of the vessels. There is no doubt in my mind that the method is fraught with danger, owing to the action chloral has upon the heart. Trélat adds **morphine** to the combination, and thereby, I think, increases its danger.

Cocaine and chloroform (Obalinski).—The plan recommended is to allow the patient to inhale chloroform in the ordinary way until he is slightly under its influence, and then to inject cocaine hypodermically. The dose is given as gr. $\frac{1}{2}$ to gr. $\frac{1}{4}$ of a 3 per cent. solution. It is claimed that less chloroform is required, and that fewer "after effects" follow the use of the combination. However, cocaine does not antagonise chloroform, as is sometimes stated, but tends to increase the risk of heart failure, so that I think Obalinski's method is not to be recommended.

Rosenberg paints the nasal mucous membrane with cocaine before giving chloroform, as he contends this obviates reflex cardiac inhibition due to irritation of the fifth pair of nerves by the chloroform vapour.*

Chlorbutol (Chloretone) has been recommended for use before general anæsthetics in order to produce drowsiness and to lessen or prevent after-sickness. Fifteen grains are given by the mouth three hours before the inhalation. Chlorbutol evaporates slowly at room temperature, and so cannot be well sterilised by heat and does not maintain its strength if kept for any length of time.

* *Berliner Klin. Wochens.*, Jan. 7 and 14, 1895.

CHAPTER VIII.

ANÆSTHETICS IN SPECIAL SURGERY.

THE choice of the anæsthetic has been already discussed ; it now remains to consider such special methods and precautions as may be required to obtain satisfactory anæsthesia during the performance of special operations.

Operations on the brain and spinal cord.—The method which answers best when the brain is being operated upon is to employ chloroform in association with oxygen from the Vernon Harcourt apparatus shown in fig. 52, p. 244. It is often extremely difficult to obtain anæsthetic sleep in patients who have taken large quantities of narcotic drugs, and the induction period in these cases is frequently prolonged. Any attempt to hasten anæsthesia by using strong percentages is extremely dangerous. On the other hand, many persons who have to be operated upon for brain or meningeal disease are, at the time of taking the anæsthetic very prostrate and semi-comatose, or suffer from the results of intra-cranial pressure. These conditions render interference with the circulation and respiration dangerous. The patient, when once anæsthetised, will often remain so with very little or even without any more of the anæsthetic. As a rule, when the intra-cranial pressure is relieved the respiration greatly improves, but until the cranium has been opened and the dura mater incised, breathing may be very unsatisfactory, and even may cause alarm if, owing to the steps of the operation, increased pressure occurs. When the breathing is at all hampered the chloroform should be withheld altogether for a time, until it improves, when more chloroform can be given, care being taken that the strength of the

vapour is as slight as is consistent with maintenance of anæsthesia. As a rule, when induction is complete, 0·5 per cent. to 1 per cent. is sufficient. In operations upon the **cerebellum**, the dangers of respiratory failure and shock are even more imminent, especially if there is pressure on the medulla. It may happen that, as soon as the trephine is applied, the breathing ceases. If the patient has been deeply anæsthetised, death is very likely to occur ; but if only 1 per cent. of vapour



FIG. 75.—Carter Braine's arm-rest.

is being inhaled, the chances are in favour of the life being saved, since, as soon as the pressure is relieved, the breathing starts afresh, and the blood pressure rapidly regains its normal height. I have known cases of cerebral and cerebellar abscess in which this respiratory failure occurred ; as, however, only small quantities of chloroform had been inhaled the patients recovered, and the operations were satisfactorily completed. Ether produces too much vascular excitement in the meninges and brain substance, and so is contra-indicated for these cases. In treating the collapse—often very severe—I have found inhalation of warmed oxygen, raising the tempera-

ture of the body by hot water bottles, and towels wrung out of hot water, and hypodermic injections of digitaline, to be the most valuable means to adopt. The circulatory depression is often extremely severe. Some anæsthetists employ an open ether method after a preliminary injection of atropine, and state that no undue rise of blood pressure ensues. Dr. Mennell, comparing the hedonal infusion method with the chloroform and with the open ether methods, is inclined to favour hedonal provided that the amount of hedonal given is restricted and the administrator is familiar with the dangerous properties of the drug.

The posture of the patient during intra-cranial surgery is important. The head must be kept high, and the uppermost arm kept off the chest by the use of an arm-rest. That of Mr. Carter Braine is an excellent device.

Operations upon the spinal cord present similar dangers, from the point of view of the anæsthetist, to those which occur when the brain is the seat of operation. In them, also, it often happens that, owing to the lesion in the cord, the respiration is embarrassed *ab initio* through paralysis of the muscles concerned in the respiratory movements. The posture necessary for the performance of the operation is a further source of difficulty and danger. Chloroform should be employed in these cases, and in very dilute vapour, and oxygen freely given to avoid any asphyxial complication. When anæsthesia is established, no more chloroform need be given unless the patient begins to regain consciousness or shows signs of vomiting. It is often surprising how little—1 per cent. or less of chloroform—is required to maintain anæsthesia in these cases. The lateral posture is best with the uppermost arm kept off the chest by means of an arm-rest. The arm-rest checks the tendency for the patient to roll over on his chest and so interfere with his breathing. It is better to avoid giving scopolamorphine in operations upon the central nervous system.

ANÆSTHETICS IN OPHTHALMIC PRACTICE.

Most of the operations performed by ophthalmic surgeons are done with the aid of cocaine, eucaine, or other local

analgesics, and the reader is referred to the chapter dealing with these substances. When general anæsthesia is desired, the choice falls upon chloroform, ethyl chloride, the A.C.E., or gas and ether. As extreme stillness is a necessity in operations such as iridectomy, narcosis must be of the third degree, and great care must be taken that this is maintained lest coughing or straining occur, as this might prove most disastrous. Even with great care it is not always easy to prevent the patient passing into the fourth degree of narcosis. This contingency must be looked for carefully and prompt measures taken to avoid the great danger of over-dosage. Deaths have been caused by neglect of this. It is of paramount importance that the operation should not be commenced until the patient is profoundly narcotised. When anæsthesia has been obtained, the mask, or inhaler, can be lifted from the face, and as a rule the operation can be finished without any further inhalation being required. In very feeble or asthenic subjects, I have employed ethyl chloride with success, following it with ether given in an atmosphere of oxygen. For brief operations ethyl chloride answers very well, but in cases in which after-vomiting is likely to prove dangerous, ethyl chloride should be avoided and nitrous oxide and oxygen be substituted. For excision of the eyeball the gas-ether sequence is excellent, especially if oxygen is freely admitted throughout the operation.

ANÆSTHETICS FOR OPERATIONS ABOUT THE MOUTH, JAWS, AND RESPIRATORY TRACT.

For the selection of the anæsthetic, see p. 48. In dental operations, see pp. 65 and 429.

During the removal of loose sequestra from the jaws, excision of an epulis, tapping antral abscess, etc., very deep narcosis is not requisite, and chloroform may be given from a mask. If the operation occupies more than a minute or so, anæsthesia should be kept up after removal of the mask by the use of a mouth tube connected with a Junker's inhaler (p. 256). When the operation is very brief, nitrous oxide, or ethyl chloride, will amply suffice. If ether is used in these cases, as in some parts of the United States, the anæsthetic

must be pushed so that the patient's blood becomes strongly charged with it. When the inhaler is removed, chloroform can, if need arise, be given by a Junker's apparatus through a nasal or mouth tube. Oxygen is a valuable help when the patient is inhaling the ether, as it permits more of the anæsthetic being taken and obviates cyanosis, or venous congestion. When ether is to be relied upon solely for operations on the mouth or nose, it is essential to obtain a very profound narcosis by it before the operation is commenced. This can only be done by allowing a prolonged period of full inhalation. Oxygen given with the ether facilitates this, and ensures a more lasting and profound narcosis. I have on more than one occasion given ether, the circumstances of the cases contra-indicating another anæsthetic, for removal of the upper jaw, and found the method extremely satisfactory.*

During the removal of the upper jaw the patient must be kept deeply under the anæsthetic for the skin incisions. A choice of several methods exists. In the case of feeble people or those broken in health by alcoholic excess the induction of anæsthesia may be brought about by ethyl chloride and ether, chloroform being given subsequently from a mask. As, however, this plan may cause congestion and increase the after bleeding, I usually commence with chloroform, using a Vernon Harcourt's inhaler, and, when the third degree is reached, give a few breaths from a mask, continuing the supply of chloroform by means of a mouth tube and Junker's inhaler. Some persons are difficult to keep quiet with the mouth tube. To meet this, the mask should be applied, as opportunity arises, to supplement the vapour passing through the tube. When the skin flaps and soft parts are freely divided and dissected up, the patient must be allowed to enter the second degree of narcosis, so as to be able to cough and prevent blood entering the larynx, although he should be sufficiently anæsthetised as not to struggle. The management of these cases needs constant care and some judgment. The dangers the chloroformist has to guard against are—entrance of blood, teeth, portions

* Ether vapour can be blown through a Junker's apparatus if it is kept warm enough to avoid the tubes getting "snowed" through rapid ether evaporation.

of growth, spicules of bone into the larynx ; and interference with the operation by the patient becoming partially conscious. If struggling occurs when there is much hæmorrhage, the danger of the operation is increased greatly. The chloroformist should see that the spurting of blood from vessels is directed out of the mouth ; that the tongue is not allowed to fall back ; and that the air enters and leaves the lungs freely. If the patient's respiration is embarrassed from entrance of blood into the air-passages, the tongue must be drawn well out of the mouth, all blood mopped away, and, failing relief from this, laryngotomy performed and the air-passages cleared of clot ; subsequently the tube must be kept free from clots, etc., by aspiration, or by sucking them out from the tube. Inversion may be needed.

Removal of the lower jaw may often be done almost completely while the patient is under ether, the ether being given in the manner already described, and chloroform administered only just at the last when, in the course of the operation, the mouth is opened. This is an admirable method. Many surgeons prefer the use of chloroform throughout the whole operation.

In excision of the tongue the patient, having been anæsthetised by ethyl chloride and ether, or by chloroform, one of the methods already described being adopted, chloroform is subsequently administered through a nasal or mouth tube. The same precautions with regard to hæmorrhage should be taken as in anæthetising for removal of the jaws. When much bleeding occurs the patient must be guarded from deep narcosis. In Kocher's operation ether can be used until the floor of the mouth is opened, and the tongue drawn out of the wound ; at this point chloroform is exhibited through a nasal or mouth tube. Many prefer the use of chloroform throughout the operation.

When small growths are removed from the tongue, nitrous oxide or ethyl chloride answers perfectly well. The nitrous oxide anæsthesia may be maintained by using the "injector," or Coleman's nasal apparatus, while the surgeon is operating, although the venous congestion which is incidental to these methods is a detriment. Preliminary injections of scopolamine and atropine are advisable in all these cases,

although the dose must be small, since the essence of the anæsthetic technique consists in preserving the laryngeal reflex.

There are the following alternative methods which are mentioned in the order of the value:—

Ether infusion after atropine.—Especially is this of value in prolonged operations on carcinomatous glands which are removed prior to the removal of the tongue, and those in which the operation involves the floor of the mouth or tonsils. The utmost care is needed unless a preliminary tracheotomy with plugging of the retropharynx and larynx has been performed, in order that no blood may enter the air-ways. Although the narcosis with ether infusion is light, the tongue commonly has a tendency to fall back while the protective cough reflex is blunted. These dangers must be kept in mind and precautions adopted. The anæsthetist should not be placed in a position in which he cannot see the field of operation and keep control of the tongue and larynx. **Hedonal or isopral infusion** is not a safe procedure in these cases, as the narcosis is apt to deepen after the completion of the operation, and so suffocation from even trifling bleeding may easily occur and pass unnoticed.

Pharyngeal anæsthesia, by means of Crile's tubes, is very valuable for some of these operations, although it is obvious that the method cannot for anatomical reasons be adopted for all of them. When employed the patient is anæsthetised by the usual route and subsequently the pharynx is blocked. The narcosis is usually light.

Intra-tracheal insufflation of ether in the hands of one familiar with the method offers peculiar advantages as it at once supplies an excellent anæsthesia, renders it possible to employ a stimulating anæsthetic, and safeguards the patient from the dangers of aspirating blood into the air passages. It, however, like the Teter method of giving **nitrous oxide** and **oxygen** for these operations, requires great skill and experience, and should not be attempted until complete mastery of the methods has been obtained by their frequent employment in cases of a simpler nature.

Rectal etherisation and colonic absorption methods are useful, and should be preceded by the use of alkaloids. Anæsthesia should be induced by mouth inhalation.

In severe operations of this class it is often advisable to perform a preliminary tracheotomy and to plug the upper aperture of the larynx. The first stage is done under usual methods, and subsequently chloroform vapour with oxygen is propelled by a Junker's apparatus and tube directly into the trachea through the tube. The spasm which usually follows the introduction of the tube may be troublesome, but it is easily controlled by spraying with cocaine. Where chloroform is given directly into the trachea, since the "dead space" is so materially diminished, very much less of the anæsthetic is required. Cessation of respiration will occur unless the anæsthetic is given lightly.

It is usually an advantage to have the tongue kept well forward, although not so much so as to drag the epiglottis out of position thus leaving the larynx unprotected. To do this it is better to introduce a ligature into the tongue rather than to crush it by means of tongue forceps, as less after-discomfort will result.

Staphylorrhaphy.—The chloroform is given from a modified Junker until the third degree of narcosis is fully reached. The Whitehead's gag is then fixed, chloroform being inhaled through a mouth tube. The tongue depressor should be so arranged as not to interfere with respiration. The chin is best tilted up a little, as, if it is allowed to drop, breathing is always hampered. Anæsthesia can be perfectly well maintained in this way until the operation is complete. Mr. Warrington Haward tells me he has used ether successfully for these cases, but I have no personal experience of its use in this connexion, except when given by the rectal route, a method which answers very well. The hæmorrhage being, as a rule, slight and easily controlled, there is no particular fear of blood entering the trachea, and further, as quietness is very desirable in the patient, full surgical narcosis should be maintained. Some surgeons employ the semi-inverted position for these operations, and this posture certainly lessens the danger of blood entering the larynx.

Operations on the respiratory tract. **Laryngotomy or tracheotomy** is best performed when the patient is under chloroform, although an operation without complications can

be carried out quite satisfactorily when ethyl chloride is given, provided respiratory embarrassment is absent. When dyspnoea exists, chloroform should be employed, its use being so restricted that the patient is only lightly narcotised. While complete anæsthesia is requisite, any dulling of the respiratory centre is to be avoided. In cases of diphtheria the heart is always profoundly affected by the disease, and is peculiarly liable to suffer from even slight excess in the strength of the chloroform vapour inhaled. It is very important in such cases to employ a regulating inhaler, so that the amount given can be accurately known and the supply cut off at any moment.

Operations upon the thymus.—These are seldom attempted in this country, nor is their necessity likely to arise save in most exceptional cases. They are usually performed under chloroform unless local analgesia is relied upon. As the patients are extremely young, local methods usually fail to ensure the quietude essential to the difficult and hazardous character of the case, and so had better be avoided.

Operations on the thyroid gland.—In cases of simple adenomata no special difficulties arise unless the growths are of a large size or encircled the trachea and so cause obstruction to the air-way.

The methods commonly employed are (1) Local analgesia with preliminary injection of alkaloids; (2) General anæsthesia; (3) A combination of local analgesia and general anæsthesia (Crile's method).

1. Although the pain of the operation can be mitigated, it is usually rather severe when the growth is being displaced from its bed, and the dragging incidental to the procedure interferes with respiration and lowers blood pressure.

Braun advises the use of novocain (·5 per cent.) and suprarenin : 75 to 125 cc.m. are injected, but it is advisable to give a preliminary hypodermic of scopolamorphine. The skin is infiltrated (see below, Chap. XI.) fairly wide of the margin of the growth; subsequent subcutaneous and subfascial injections are made until it is assumed that the nerves supplying the area to be dealt with have been brought under control.

In cases of **exophthalmic goitre** the dangers to be faced are of a very much more serious nature. Not only is there

the effect incident to the operation, but there is in these cases a very real danger of sudden heart failure often arising from a disproportionately slight cause. For these patients some authorities contend that local analgesia, by not abrogating "psychic shock," does not free the patient from risk, and suggest the employment of scopolamorphine before local analgesia or Crile's full technique (*vide infra*).

2. **General anæsthesia.**—(1) Chloroform given by a regulating inhaler consequent to scopolamorphine and atropine is, I think, less dangerous than is often stated. The atropine dries up the bronchial and salivary secretions which are apt to be excessive in persons with goitre. The narcosis, after anæsthesia is established, should be light with the conjunctival reflex present, and oxygen should be freely given. Slight reaction when the thyroid is dislocated is desirable.

(2) Open ether after atropine is a fairly safe procedure, provided no venous congestion is allowed to arise.

3. **Crile's method.**—Nitrous oxide and oxygen is given daily (Teter's method), the patient being told this procedure is for treatment, while the real date of the operation is kept a secret. On the day that the thyroid is to be dealt with, a hypodermic injection of scopolamorphine is given and nitrous oxide is administered. The patient is then taken to the operation theatre, and the operation area infiltrated with novocain. The operation is then performed, and the nitrous oxide-oxygen anæsthesia is kept up until the patient has been taken back to his room and replaced in his bed.

In my own practice I have commonly used **chloroform** and **oxygen**, and have found the method satisfactory. The use of **ether** is open to one **objection**, which has only to be mentioned to be guarded against. It is this. While under the stimulating effect of this anæsthetic the patient is apt to appear spuriously free from shock, and the anæsthetist may be apt to form too optimistic a view of his condition, so that the surgeon may perform a more radical operation than he at first contemplated. As soon as the ether inhalation is stopped, however, the patient falls into grave shock, so that the chances of his ultimate recovery are materially prejudiced. I know of one case at least in which the patient succumbed in a few hours from this cause.

In cases of suppuration involving the tissues about the trachea, as in **angina Ludovici**, the danger of suffocation is always present, and chloroform must be given most guardedly. Deaths have been caused in the case of persons with obstructed breathing by the use both of nitrous oxide and by that of ether. These anæsthetics are inappropriate, and should never be employed when this condition is present.

Excision of the larynx. **Thyrotomy** requiring a preliminary tracheotomy may be performed while chloroform is given by sprinkling it on a flannel stretched across a funnel connected with a Hahn's tube, or by directing a catheter over the outlet of the Hahn's or of an ordinary tracheotomy tube, and pumping chloroformed air through it from a Junker's inhaler. An alternative is mentioned below.

Bronchoscopy.—Chloroform is, as a rule, the best anæsthetic for induction, and the passage of the instrument is rendered easier if the larynx and epiglottis have been sprayed with cocaine solution. Complete anæsthesia is required, as laryngeal spasm, always liable to occur, is more pronounced during a light narcosis. It is also desirable because, if any difficulty arises during the introduction, the surgeon may require some minutes, during which the patient will not receive any anæsthetic, and so is liable to struggle unless well under chloroform. A Junker's inhaler with mouth tube should be at hand to maintain anæsthesia until the bronchoscope is safely passed. When this is done it is easy to maintain the due depth of narcosis.

These rules apply *ceteris paribus* to the passage of the endoscope into the pharynx and stomach.

RECTAL ETHERISATION IN ORAL SURGERY.

During operations for the removal of the tongue, the jaws, as well as for staphylorrhaphy, also for excision of the larynx, the rectal etherisation method is far more convenient for the operator than the plans named above in which chloroform is used. The operation can be carried on without a break. However, as some alarming and even fatal results have occurred under the care of skilled anæsthetists, it must be admitted that rectal etherisation is not wholly devoid of

danger. In most cases, although not in all, the after effects are slight and not lasting. I regard the method as a valuable alternative one in suitable cases. When much blood is likely to be effused into the buccal cavity, careful watch will have to be taken that it is efficiently sponged out, and does not enter the windpipe.* If the anæsthetist is engaged in watching the apparatus at the foot of the operating table, another observer should be stationed at the head to watch the respiration.

In all these cases the inverted posture of Trendelenburg may be usefully employed.

Ether infusion for all the above operations answers well and is, I think, safer in many cases, but here again the anæsthetist must take all requisite precautions against blood entering the air-passages and other causes of interference with respiration. I have never used this method for cases of staphylorrhaphy in children and should hesitate to do so, as chloroform appears to me to be better adapted for them.

REMOVAL OF POST-NASAL ADENOIDS, NASAL SPURS, AND INTRA-NASAL OPERATIONS.

The removal of growths in the post-nasal region may give rise to troublesome bleeding. Chloroform, preferred by many surgeons, possesses the disadvantage that the patient remains longer under its influence, and so it is less easy during its use to avoid blood entering the air-passages. The narcosis should be very light, in order that the larynx may be protected by its reflexes against the entrance of blood. Deep anæsthesia in these cases is most perilous.

Many authorities assert that the anæsthesia obtained by nitrous oxide given with oxygen or air is sufficient for removal of post-nasal vegetations. In many cases this may be so, when the anæsthetic is carefully managed and the operation is rapid. I have found this method also may be supplemented by the use of ether with most satisfactory results. There is no objection to the patient being placed in a chair, *provided chloroform is not given*. In some nasal operations

* Especially is this important if the anæsthesia is profound and the reflexes annulled.

a lengthened period of anæsthesia is required, then chloroform must be used in succession to the gas and ether, and respired through a mouth tube. In delicate children who fear "gas," ethyl chloride answers very well.

It has been stated by some anæsthetists that chloroform may be used even if the patient is in a sitting posture. Although the plan they adopt is to induce anæsthesia by ether or an ether-chloroform mixture and maintain it with chloroform vapour blown through a Junker's apparatus, I consider the method is not free from danger, especially if the patient is delicate or the respiratory obstruction is considerable.

The patient, if sitting up, is given gas and ether by Clover's method. When gas alone is used, it is well to put in position a dental prop, or Doyen's gag, before commencing the administration, otherwise much valuable time is lost in attempts to open the mouth. When the patient is well under ether, the induction being so managed that no lividity or congestion is present, the mask is removed, the gag inserted, and the operation commenced. If the patient becomes restless before its completion the mask can be reapplied, the head being tilted forward and flexed, so that the blood passes forwards and not into the air-passages. If the patient is reclining, chloroform can be given through a mouth tube as soon as the operation is commenced, the amount being carefully regulated by the requirements of the patient, and withheld entirely if any interference with breathing occurs.

As soon as the operation is completed the patient should be turned right over on to his left side and laid with the head in such a position that the blood must escape out by the nostrils and mouth. Some surgeons keep their patients on their left side throughout the operation.

The introduction of ethyl chloride has given us an extremely useful and readily managed anæsthetic for *brief* operations on the nasopharynx. It is not so serviceable, except as a means of introducing ether and chloroform, for prolonged and difficult cases, and had better be restricted to those which are unlikely to present complications.

Of course, when the cautery is used in the nasal passages,

ether must be avoided. For cauterising the turbinate bodies nitrous oxide or ethyl chloride can be used.

Tonsillotomy can be usually performed under the nitrous oxide and ether, or ethyl-chloride-ether sequence, or if open ether is preferred it will prove satisfactory especially when an open ethyl-chloride induction is practised.

Tonsillectomy, as commonly performed, requires a longer period during which the anæsthetist is debarred from complete access to the mouth and nose. Many surgeons ask for a deep degree of narcosis so that the palate and faucial arches are flaccid and no reflex movements of the pharynx and larynx occur. To this end they select chloroform for both induction and maintenance. Except in young children these cases are best managed by using a preliminary injection of alkaloids—indeed, atropine may be used for all except infants. For induction nitrous oxide or ethyl chloride followed by ether or a chloroform-ether mixture may be used and this followed by chloroform vapour from a Junker's apparatus. The tongue should be secured and kept well forward, but without strong traction, throughout the operation. I find keeping up a trickle of oxygen through a mouth tube a useful adjunct.

These methods are suggested for simple growths or hypertrophy: when a sarcoma or other malignant tonsillar growth has to be removed, ether infusion is probably the best method for adoption.

ANÆSTHETICS IN DENTAL SURGERY.

The operations for which an anæsthetic is usually needed are:—

Extraction of teeth ;

Lancing the gums, and tapping the antrum ;

Extirpation of the dental pulp ;

Filling when the dentine is abnormally sensitive.

In tooth extraction, nitrous oxide gas—alone, or with air or with oxygen—is the safest and most convenient anæsthetic.

The technique of the use of an anæsthetic is fully described on p. 77.

As a rule, it is inadvisable to administer gas twice to the same patient at one sitting, and if such a thing is done warning of probable after-headache should be given.

When prolonged anæsthesia is required, nitrous oxide may be given by the nasal method. I find it convenient to commence in the ordinary way with gas, or gas and oxygen. and, when the mask is removed and the operation commenced, I apply the nasal inhaler and continue the gas as long as is necessary. When a Coleman's apparatus is in use this complication is avoided as the mouthcap is simply dropped and the patient continues nasal inhalation. If the patient becomes dusky or jactitates, the inhaler is lifted for a breath and then is replaced. This plan is less useful in extraction of upper teeth, especially if the lip is short or pulled forward by a prognathous jaw. Ethyl chloride is valuable in suitable cases for prolonged dental operations. With 5 c.c. or 8 c.c., according to the physique of the patient, an anæsthesia can be obtained lasting sufficiently long for clearing the jaws. *Chloroform should never be given to a patient sitting upright in a dental chair.* If it is deemed wise to employ chloroform, the patient should be seen at his own home, and in bed, and the anæsthetic administered with the usual caution. Indeed, I think it is best, in every case when an extensive dental operation has to be done under an anæsthetic, that it should be performed in the home of the patient and under ordinary surgical conditions. The gas-ether sequence following an injection of atropine is the best routine method for extensive dental operations. The ether should be given freely.

THORACIC SURGERY.

In the surgical treatment of empyema some difficulty frequently arises in the choice of the anæsthetics. For short operations, such as exploratory aspiration, nitrous oxide with oxygen answers very well, and this mixture offers many advantages. It is given in the usual manner, but as soon as anæsthesia is obtained, oxygen is freely admitted. Many patients complain that the mask increases their distress and dyspnœa. Ethyl chloride is free from this drawback if given

carefully by the open method. If the dyspnœa is at all severe or the heart is displaced, it is better, I think, to rely upon chloroform and oxygen given from a regulating inhaler, as the patient suffers far less discomfort and does not incur any greater risk. The real dangers of the anæsthetic in these cases arise (1) from the fact that unless the anæsthetist is familiar with them he is liable to push the anæsthetic too far and obtain a deep narcosis, and (2) from incautious movements of the patient, who may still further hamper his already embarrassed respiration.

Prolonged operations.—Chloroform in a good many instances has caused dangerous and even fatal results from syncope, while ether sets up severe cough and respiratory distress. Sir Rickman Godlee,* whose experiences of these cases is very large, advocates chloroform provided it is given slowly, and not pushed beyond the second degree of narcosis. I believe that chloroform is, upon the whole, the safest anæsthetic in thoracic surgery, especially in the form of the (1 in 10) alcohol-chloroform dilution. If pure chloroform is used it should be given from a **regulating inhaler**, and **oxygen** freely mixed with it.

For resection of ribs the patient is slowly anæsthetised, and as soon as he passes into the third degree the tissues are divided down to the rib. He is then passed into the second degree, and this suffices for the rest of the operation. If there is a large amount of secretion, the lighter the narcosis the greater will be the patient's safety. Any change of posture must be carefully noted, and if the breathing is impeded, or coughing excited, the patient must be replaced in the posture of greatest ease. It is often a good plan in very severe cases—*i.e.* when grave fears exist owing to the condition of the heart and lungs—to push the anæsthetic to only the first degree, as far as possible maintaining a state of analgesia, and always stopping short of true anæsthesia. To combat these difficulties I have employed the method of rectal etherisation (*q.v.*) in thoracic surgery, and have been pleased with the results, especially in the case of children. It is essential, however, in using this method to avoid too

* "Disease of the Lungs," by Sir Kingston Fowler and Sir Rickman Godlee, London, 1898, p. 114.

deep a narcosis. In one case I met with a serious complication. The lungs became waterlogged owing to the cough reflex having been lost. This was in a young subject, but inversion drained the fluid out of the sound lung and the operation was then completed and the child did well. When an empyema communicates with a bronchus great care must be taken that the patient does not become narcotised so deeply as to hinder free coughing up of the pus in his lungs. A great danger arises, when the patient is turned on his sound side, lest the pus flow into the bronchi of the healthy lung. If this occurs when the patient is deeply under the anæsthetic, asphyxia must result. Any appearance of cyanosis should be accepted as a sign to lessen the depth of the narcosis.

Intra-tracheal insufflation, provided there is not much pulmonary secretion, and no communication exists between the abscess and a bronchus, is probably the best method in thoracic surgery as it ensures a plus pressure in the lungs. For some cases conduction analgesia answers well. The thoracic nerves are sought for at the point where they divide, the anterior portion running in the groove on the under border of the ribs, and novocain injected into them (see p. 427).

The arm-rest is useful if the patient is turned partly on his side; this may be done provided that the empyema is shut off from the air-ways and no great quantity of free fluid exists. In most cases atropine should be given before the inhalation, but morphine and scopolamine are best withheld.

ANÆSTHETICS IN ABDOMINAL SURGERY.

Complete relaxation of the recti and other abdominal muscles is imperative; great quietude and freedom from hurried respiration, coughing, and vomiting, are also necessary for operations upon the abdominal parietes or viscera. To ensure these conditions, chloroform, the alcohol-chloroform, or the A.C.E. mixture, or open ether is suitable. We now have the alternative methods of ether infusion and intra-tracheal insufflation. When a general anæsthetic is in use, the patient must be kept fully under it during incision through the parietes; subsequently a lesser degree of narcotism

is needed, until the final skin sutures are put in, when full anæsthesia will again be requisite. Great care must be taken, however, that the patient is not allowed to recover sufficiently for the supervision of vomiting. In operations upon the gall bladder and its ducts, and in the region of the upper abdomen in general, it is often very difficult to effect complete relaxation of the parietal structures. This difficulty is partly anatomical in origin, and partly reflex due to handling viscera. Very commonly phonation, almost like articular groans, is caused reflexly, and that even when the conjunctival reflex is abolished, the light reflex sluggish, and the pupil contracted. These must not be allowed to mislead the anæsthetist or induce him to deepen narcosis, and so give an over-dose. In cases in which a large tumour or collection of fluid or gas is removed from the abdomen, and the heart—previously displaced—is allowed to right itself suddenly, there is especial danger of syncope, and precautions against this must be taken. The head should be kept low, and a small percentage of chloroform vapour given in order to limit the fall of blood pressure. Although many surgeons prefer chloroform in abdominal surgery, it is by no means advisable to give it in all cases. When the patient is much collapsed, or is very feeble, I have found ether with oxygen a much better and safer anæsthetic. Certainly with management it is often possible with ether to obtain as good, and sometimes even better, results than with chloroform. It is necessary that the ether should be inhaled for some time before the operation is commenced, to allow time for complete muscular relaxation. When the case is very prolonged, care is requisite to avoid too much ether being taken. This is easily accomplished, as, after having been once placed profoundly under ether, the patient requires but little more of the anæsthetic.

The plan I usually pursue is to commence with ethyl chloride, or nitrous oxide, then give ether, substituting chloroform if the operation is a prolonged one. I employ a regulating inhaler. This method is also useful in extensive operations upon the kidneys. In cases of intestinal obstruction it is well to perform lavage before the anæsthetic is administered.

It is the common practice at the present time to adopt an open ether method in abdominal operations, and especially if

acute septic infection is present, as it is believed that if chloroform is adopted it may lead to destructive changes in the liver and kidneys and lessen the patient's chances of recovery. In the face of Graham's work, which appears to show that ether, when inhaled for a long time, lessens or stays phagocytosis and agglutination for some days or weeks, it is well to adopt the precaution of injecting five ounces of pure olive oil into the bowel as soon as the operation is completed.* This procedure appears to counteract the effect of ether as regards phagocytosis and to restore that function within a few hours.

The rigidity of the recti-abdominis muscles—the bane alike of surgeon and anæsthetist—is very commonly the result of cyanosis, itself caused by some reflex or other interference with respiration. I have frequently obtained relaxation of these muscles by giving oxygen freely with the chloroform. In extreme cases I use ether and oxygen, since ether ultimately produces greater relaxation than chloroform, and I return subsequently to the use of chloroform. It has been urged that the use of closed inhalers is apt to provoke rigidity of the muscles by hampering respiration. I am convinced that such a statement is true only in part. A closed inhaler need not, if properly employed, cause any cyanosis. It is only a question of the patient's ability to fill and empty the bag attached to the inhaler, and any patient who is not very markedly collapsed will be able to do this easily ; but if he cannot do so he is not in any need of further anæsthetic. This misapprehension about the use of closed inhalers has arisen from a faulty method of using them and from the practice of not admitting sufficient air. The advantage of using a closed ether method during some part of the narcosis for extensive abdominal operations is that it keeps up the required carbon dioxide content of the blood and prevents acapnia developing. When large serous surfaces are exposed it is asserted that serious loss of carbon dioxide occurs and so acapnia is developed, a condition which, making for danger as it does, must be kept in mind during the management of these trying cases. The adoption of

* See a useful paper by Dr. Ferguson dealing with this subject, *New York Medical Journal*, June 29, 1912.

a preliminary scopolamorphine-atropine injection before the general anæsthetic should be routine, as it helps in every way. Before the open ether method it is absolutely necessary. Persons who are collapsed, and whose respiration and circulation are, as the result of disease or surgical shock, in a feeble and almost failing condition, can be stimulated by freely pouring ether upon an Allis' inhaler or even upon a mask. As soon as they improve—and they will do so in a few minutes—ether and oxygen from a closed inhaler can be substituted with advantage, followed, if need be, by chloroform from a regulating inhaler.

For skin incisions local analgesia may be used, but the subsequent manipulation of the viscera generally causes pain and may induce vomiting and faintness. These may demand the use of a general anæsthetic.

In the case of abdominal operations undertaken during extreme shock or which involve the likelihood of the onset of shock, the infusion ether method offers peculiar advantages. It should, however, be carefully watched and if too profound narcosis occurs the ether should be very much lessened, or even simply saline should be infused. What has already been said about the danger of excessive stimulation by ether applies especially to this type of case.

In the **radical cure of hernia and inguinal colotomy**, ether answers perfectly well. Both these operations can in some cases be done under local analgesia, but not if the patient is timid and liable to shock.

Dr. Crile's system, which he claims is of great value in abdominal surgery, is to employ a general anæsthetic—preferably nitrous oxide and oxygen—associated with local infiltration of all the tissues involved in the incisions. The parietes are infiltrated with novocain, but the peritoneal tissues receive hydrochloride of urea and quinine, since this agent ensures analgesia for some days after the operation (see p. 416).

Spinal analgesia supplies an alternative method for operations on the lower abdomen and pelvis, and is preferred by some surgeons for emergency operations such as acute strangulation of the intestine and obstruction. In this last condition, however, the same danger of faecal drowning is

present as when a general anæsthetic is given, and deaths from this cause have been recorded even though spinal injection had been practised.

INTESTINAL OBSTRUCTION.

The methods in most common use for obtaining anæsthesia in this condition are : (1) the employment of a general anæsthetic ; (2) spinal analgesia ; (3) local analgesia.

(1) In view of the fact that the main danger arises from regurgitation of the contents of the stomach and intestines as soon as the tonus of the muscle at the cardiac and pyloric orifices is lessened by the anæsthetic it is best to adopt lavage before the anæsthetic is commenced. Some patients are too feeble to allow of this, and even after lavage fresh regurgitation is liable to occur, so that a light narcosis is essential to preserve the laryngeal reflex, while the patient's shoulders and head are placed rather high. In extreme cases the initial incisions can be performed under local analgesia, general anæsthesia being adopted later when manipulation of the abdominal viscera is taking place. The plan* I have suggested, although it involves the extra risk of performing a preliminary laryngotomy, safeguards the patient from fæcal drowning. It consists in giving the anæsthetic by a laryngotomy opening after completely blocking the upper opening of the air-ways by careful packing and the introduction of a double stomach tube through which that viscus is irrigated continuously. The laryngotomy can be done under local analgesia ; the packing must be carefully and thoroughly carried out. The adoption of intra-tracheal insufflation would appear to be an excellent substitute for this plan, except that there is a danger lest stercoraceous material should become aspirated before the intubation can be carried out. With regard to (2) and (3) no detailed description is needed as either method is conducted on routine lines (see Chapter XI.).

* *Brit. Med. Jour.*, April 23, 1910 : "Fæcal Vomiting during Anæsthesia, a suggested method of obviating its danger."

PELVIC SURGERY.

For the usual gynæcological operations ethyl chloride alone in very brief cases, or followed by ether for longer ones, may be used. The lithotomy position, especially in obese subjects, sometimes gives rise to respiratory embarrassment and circulatory depression which may produce faintness or syncope. I know of one case at least in which breathing ceased and the patient was only restored by being placed horizontal while artificial respiration was performed. Mr. C. J. Bond * (of Leicester) has advanced reasons for believing that the displacement of the heart due to posture produces marked circulatory changes. It is probable that the lithotomy position may cause dislocation of the heart, and that the syncope arising from this posture is due as much to interference with the heart's action as to embarrassment of respiration.

Operations about the bladder, such as prostatectomy, require deep narcosis to enable the surgeon to introduce his fingers into the bladder. I find the ethyl-chloride-ether-chloroform sequence is the best for such cases, and that it is imperative that the patient should be thoroughly relaxed *before* the operation is commenced. If this is not done, spasmodic contraction of the muscles may occur, which is very difficult to overcome when once established. At the time that the prostate is being dragged from its bed serious shock is likely to occur, so that in feeble subjects it is best to give ether after complete relaxation has been obtained.

The Trendelenburg position, used both in abdominal and pelvic surgery, will sometimes give rise to difficulties somewhat similar to those which occur in the lithotomy posture. When the diaphragm is forced up, especially in the case of short, stout persons, duskiess with embarrassed breathing and cardiac distress may arise.† These should be watched for, and the position corrected before more dangerous symptoms arise. In feeble, anæmic subjects, the head-down

* *Brit. Med. Jour.*, Dec. 12, 1885.

† Mr. Carter Braine has recorded a case in which œdema of the face became developed as a result of the inverted position.

position is often distinctly helpful, but in these, as in all cases, great care is necessary to avoid any jerk or suddenness in altering the relative positions of the poles of the patient's body. In some operations a rolled pillow is placed under the patient's back to push forward the liver. This is very prone to embarrass both respiration and circulation. It is better, when possible, to allow time for circulation to right itself before the operation is proceeded with. The pillow should not be placed under the back until anæsthesia has been induced.

RECTAL SURGERY.

All operations about the anus and rectum are not only very painful, but excite reflex straining and spasm. In anæsthetising for such operations, profound narcosis is needful. The sequence of gas and ether in most cases answers well, although it is necessary to give enough ether to induce absolute muscular flaccidity, snoring respiration, and widely dilated pupils—and further, to maintain deep narcosis to the end of the operation. Most authorities regard ether as the safest agent for these cases, since less reflex shock arises under it than under chloroform. The patients are commonly anæmic and in feeble health, and need much care and watchfulness.

In such severe operations as Kraske's there is commonly a marked fall of blood pressure so that the pulse should be kept under observation. The posture, the loss of blood, and the shock render these operations especially anxious ones for the anæsthetist. It is necessary to decrease the amount of anæsthetic given when the hæmorrhage causes material shock.

CHAPTER IX.

ANÆSTHETICS IN OBSTETRIC PRACTICE.

Choice of anæsthetics ; stage when to be administered.

—As a rule chloroform is preferable to ether. When an obstetric operation is to be performed, or when the patient is greatly depressed by hæmorrhage or shock, and when it is desired to promote uterine contraction, ether may be selected. Chloroform is preferable in eclampsia and in cases of retained placenta. The A.C.E. and alcohol-chloroform mixtures also answer admirably. Otis, of Boston, employed in obstetric practice a mixture of ethyl bromide 1 part, chloroform 3 parts, and alcohol 4 parts ; of this preparation he speaks highly.

Snow advised that chloroform should be withheld until the *os uteri* is fully dilated and well-marked expulsive pains have appeared. He, however, made an exception to this rule when, during an earlier stage, the pains were very severe. When there is spasm of the cervix, if chloroform is given in the first stage for 20 or 30 minutes, the spasm relaxes and the pains, which were very severe before, become easier ; as the patient recovers from the anæsthetic, labour is accelerated.

Spiegelberg extols the employment of an anæsthetic for neuralgia and cramps occurring during parturition.

In normal labour little chloroform is needed ; if a very dilute vapour is inhaled the patient sinks into a quiet sleep, and her sensibility to pain is lessened. The second degree (Snow) of narcosis is quite sufficient for ordinary cases. The uterine contractions are but slightly affected. Although during the pains the woman may groan and appear restless,

her complaints are but slight, and as soon as the pain passes off she again falls asleep.

Rules guiding the administration :—

1. Quietude in the room is essential; fresh air should be admitted from time to time, and the patient's posture should be unconstrained.
2. Chloroform should be commenced when the labour is in its second stage if the pains are very acute, but if they are not it is best to wait until the foetal head is on the perinæum. As a rule the chloroform should not be given during the intervals between the pains, unless the severity of the pains is very great, or it is deemed advisable to induce deep anæsthesia for the performance of an obstetric operation.
3. For nervous women and those who dread pain, also in cases where the perinæum is very rigid, chloroform should be used, to relax the perineal structures.
4. In the event of the patient becoming excited by the chloroform, whenever it is deemed necessary for the woman to be anæsthetised, chloroform should be pushed to full anæsthesia.
5. In protracted labour, when the patient is to be kept anæsthetic, it is better to intermit the inhalation, to avoid an injurious accumulation of the drug.
6. Deep anæsthesia must be obtained when an obstetric operation becomes necessary (Charpentier).
7. The advisability of giving an anæsthetic to a woman in labour when heart, lung, or kidney disease exists, must be determined by the same general principles which guide us in deciding under similar circumstances in surgical cases.
8. It is necessary when the patient is kept wholly or partially under an anæsthetic, to carefully guard against over-distension of her bladder.
9. It is inexpedient to awaken the patient to consciousness by artificial means, *e.g.* slapping with a wet towel.
10. When the foetal head bears on the perinæum, the anæsthetic should be given more freely, as it relieves the increased pain, and also relaxes the maternal

passages, while it lessens the probability of rupturing the perinæum.

11. Should the patient be depressed or the pains sluggish during the administration of an anæsthetic, an occasional stimulant may be administered. This practice should be confined within narrow limits, and when pursued, sal volatile is the best stimulant to employ.
12. If the anæsthetic appears to interfere with the progress of labour, it may be necessary to suspend its use for a time and re-administer it after an interval, or even to withdraw it altogether. Chloroform is best avoided if a meal has been recently taken, since the vomiting which is likely to follow will impede delivery.

Objections.—These, although strenuously urged by some, are probably more theoretical than real.

1. Chloroform is said to increase the mortality alike among mothers and children.

Statistics certainly negative this statement. It has been shown that the danger to the parturient is *ceteris paribus* in direct proportion to the amount of pain experienced, and since chloroform minimises the pain, it lessens the actual danger of childbirth.

2. It is asserted that it protracts the labour.

Dönhoff* gives the results of his researches with the tokodynamometer. Light narcosis under chloroform lessened, but deeper narcosis abrogated, uterine contractions. Hence, chloroform is the best anæsthetic in cases of threatened rupture of the uterus with transverse presentation and loss of amniotic fluid.

Deep narcosis renders the voluntary abdominal muscles lax, and so interferes with expulsive efforts. Very deep narcosis also paralyses the uterine muscular tissue. On the other hand, a womb, exhausted by frequent and ineffectual contractions, often will regain tone under chloroform and resume vigorous expulsive movements.

3. Rupture of the perinæum is said to be more frequent when chloroform is used, but both experience and *a priori*

* *Arch. f. Gynäkol.*, Bd. 42, p. 305.

reasoning point to the reverse being true, since under chloroform the violence of the expulsive pains is lessened and the perineal structures are relaxed. The fact that, in cases of rigid perinæum, chloroform is given may account for the statement. The present practice is to produce deep narcosis in such patients, with the express view of saving the perinæum.

4. Complications are asserted to be more liable to occur when an anæsthetic is used.

This point was carefully investigated by the Chloroform Committee of the then Royal Medical and Chirurgical Society, and it was found that chloroform, when properly administered, does not predispose to inflammation, puerperal convulsion, apoplexy, or other mishap.

Opinions differ as to whether it predisposes to imperfect contraction of the uterus and so to *post-partum* hæmorrhage. The answer to this question depends, first on the degree of narcosis arrived at, and secondly on the length of time allowed to elapse before its use, and thirdly on the duration of its employment and especially after the birth of the fœtal head. It is also highly important that the patient's respiration should be free and unhampered by her posture. Lactation is not injuriously affected, nor is the child in any way injured.

Convalescence, so far from being delayed, is actually accelerated by the use of chloroform in childbirth. This is probably explained by the fact that when an anæsthetic is used the nervous system is protected from shock (Sansom).

Method of exhibition.—When chloroform is employed the open method is the simplest, admitting as it does plenty of air. A little chloroform may be sprinkled on cotton-wool in a glass tumbler, and the patient allowed to hold this, so that when she grows drowsy the improvised inhaler drops from the hand. Care must be taken, if lint or a towel is used, that the face does not fall over the chloroformed cloth, or the breathing become impeded by the pillow or bedding. The Vernon Harcourt inhaler is excellent in labour. The body of the instrument is hung over the back of the bed and the face-piece connected with it by a length of flexible tubing. The patient holds the mask over her face as long as she is conscious, and as soon as her grasp relaxes the mask falls away from her.

"When deep anæsthesia is required it is best to have a skilled administrator" (Chloroform Committee, Roy. Med. and Chir. Soc.).

When chloroform, or the A.C.E. mixture, is administered by a person who gives himself up solely to this duty, the use of the Vernon Harcourt regulator, or of Junker's inhaler fitted with the glass mask (see p. 256), has the advantage of allowing less escape of vapour into the room, so that the air is kept more pure. This is especially important when the chamber is lighted by gas or oil lamps (see p. 297).

IN THE FIRST STAGE OF LABOUR, chloroform or the A.C.E. mixture, if required at all, should be given intermittently and in small quantities, except in the case of spasm of the cervix, when complete narcosis is needed. As a rule the first degree of narcosis is deep enough. The patient is conscious, but only slightly alive to painful sensations. If any excitement and disorderly conduct follow, the patient must be allowed to recover her self-control. Some persons need more chloroform than others, so that the administrator must decide each case upon its own merits, and further must be guided by his own observations, and not influenced solely by the patient's cry of "Give me some more." Women frequently repeat this phrase when almost unconscious and unaware of preferring any request. However, if chloral hydrate in grs. 15 until 30 to 40 grs. have been given in the first stage, the amount of chloroform required later on will be small.*

IN THE SECOND STAGE, chloroform should be given only during the pains, and then merely to slight narcosis, since the woman needs the use of the abdominal muscles. At the stage of labour when the head is traversing the perinæum, deeper narcosis is needed to relax the soft parts, whilst at the last, as the head emerges through the vulva, chloroform should be freely administered.

WHEN INSTRUMENTAL PROCEDURE is requisite, deeper narcosis is needful, and especial caution is required in order to prevent the patient being made simply excited and rigid—

* When chloral hydrate has been given in the first stage, caution must be practised if chloroform is administered later. If the patient is drowsy and obviously still under the influence of the chloral hydrate, very little if any chloroform should be used.

a condition alike dangerous to the mother and the child. In this stage the narcosis must be deepened and true anæsthesia obtained.

OBSTETRIC OPERATIONS.

For *Version* and instrumental deliveries, if an anæsthetic is employed, full anæsthesia is requisite and may be obtained either by chloroform, the A.C. mixture, ether, or by Otis's mixture. In deep narcosis from chloroform the parturient is probably placed in the same danger of over-dosage as when anæsthetised for any surgical operation. Many practitioners employ the A.C.E. mixture in all their obstetric cases, and give it from a cone or Rendle's mask. Ether is but little used in this country in obstetric surgery. It is sometimes urged against it that it does not relax the uterine tissue so effectually as chloroform. If this objection is valid it tells also the other way, as under such circumstances hæmorrhage would be less likely to be severe. The ether effect, moreover, passes off more rapidly.

For **extraction by forceps** narcosis sufficiently deep to keep the patient quiet is needed. Some authorities prefer the use of ether in these cases.

Craniotomy. — Hour - glass contraction. — Retained placenta.—In these cases complete relaxation is necessary, but as the patient is often very collapsed, great care has to be taken that the anæsthetic is not unduly pushed.

Puerperal convulsions.—Chloroform was formerly used in all cases of convulsions associated with labour. It is, however, contra-indicated in apoplectic seizures. The modern practice is to use morphine, hot-air baths, etc., and only to give chloroform if other means fail. It is believed that prolonged inhalation of chloroform produces a deleterious effect upon the patient.

AFTER EFFECTS.

After prolonged chloroformisation dryness of the mouth and throat and great thirst are sometimes complained of, and can

be relieved by sipping hot water and wiping the tongue with glycerine and borax, or by sucking thinly sliced lemon.

Vomiting is rare ; faintness, excitement, and headache have sometimes been manifested, but as a rule few unpleasant results follow the use of chloroform in childbirth.

GAUSS' "DÄMMERSCHLAF" METHOD.

It is now some years since Dr. Karl Gauss of Friedburg suggested his system of lessening the pangs of childbirth by the use of scopolamine and morphine. The condition which Gauss terms "dämmerschlaf" or twilight sleep is obtained as follows :—

Two separate sterile solutions are prepared ; one a 0·03 per cent. aqueous solution of crystalline scopolamine hydrobromide, and the other a 1 per cent. aqueous solution of morphine.

When the pains recur about every five or six minutes, and persist for thirty seconds, the woman is given a hypodermic injection of 1 to 1·5 c.c. of the solution of scopolamine hydrobromide (*i.e.* 0·30 to 0·45 milligramme), with 1 c.c. of the morphine solution (*i.e.* 0·01 gramme). Half an hour after this the woman is shown some familiar object, such as a pair of scissors or a skein of wool. In another half-hour she is questioned as to whether she remembers the object, and if she does not she is considered to be in a satisfactory condition (dämmerschlaf). This testing is continued at intervals, and according to the response the patient has or has not further injections. Such injections should be 0·5 c.c. to 1 c.c. of the scopolamine solution ; the morphine is not repeated as it interferes with the expulsive power of the uterine muscle. As a rule four injections suffice, given at intervals of an hour. About 0·75 milligramme is an average of the *total* amount of scopolamine required, although much less will often suffice.

During the carrying out of the method the utmost quiet is enjoined ; Gauss even insists upon blocking the ears of the patient with cotton-wool. The common causes of failure are (1) commencing the injections too early, (2) giving them too rapidly and in too large doses, (3) giving the injection at too

short an interval before the birth. The dangers are—interference with the expulsive power of the uterus, the onset of hallucinations, and restlessness, all due to over-dosage.

Scopolamine may weaken the heart if given in excessive doses, and so Dr. Abbott of Chicago adds cactina to the injection to obviate this. However, the value of this drug as a heart stimulant is not universally acknowledged. In some cases the child appears to suffer : its breathing is slow, and cyanosis with heart-feebleness appears. After delivery, as well as during the period of preparation, the woman needs constant and most careful watching, and the same care is needed for the infant until the effects of the drugs have passed off. Dr. Gauss reaffirmed his belief in the safety and value of the method before the Seventeenth International Congress (Sub-section of Anæsthetics).

In this country Dr. Ayres of Stourbridge, and Dr. Giuseppe of Felixtowe, amongst others, have practised this system, and have expressed their satisfaction with it. It may be pointed out that although scopolamine and hyoscine are closely allied, yet they are not pharmacologically interchangeable—indeed, scopolamine appears to differ in its physiological behaviour according to the source from which it is obtained, so that it is essential that reliable samples should be obtained.

CHAPTER X.

THE ACCIDENTS AND AFTER EFFECTS OF ANÆSTHESIA AND THEIR TREATMENT.

Prophylaxis.—Before considering in detail the accidents and dangerous after effects of anæsthesia, it may be useful to indicate what precautions should be taken to obviate their occurrence.

Accidents arise from the following, among many causes :—

(1) Peculiar states of the patient. **Lymphatism—status lymphaticus**—has, during the last few years, received great attention, and the belief has gradually gained ground that patients who suffer from the condition so called are peculiarly liable to die under an anæsthetic. This fact, however, is not correctly expressed, for such persons are peculiarly liable to sudden death from many other causes, causes which seem wholly inadequate to superinduce death. The author has discussed this question very fully elsewhere.* The main phenomena in this condition are : universal hyperplasia of the lymphoid structures of the body ; *e.g.* the follicles of the tongue, the glands of the neck, axillæ, groin, abdomen are enlarged ; post-nasal adenoid vegetations, enlarged tonsils are present ; a persistent thymus is common, while in 50 per cent. of the cases the thyroid is enlarged. The patient is commonly irritable ; inclined to be fat, and easily fatigued, pasty of look, with cold extremities. The heart is often small, as is the aorta, and the circulation sluggish. Thymic asthma may exist, but not commonly. There is, however, great difficulty in deciding during life whether any given child suffers from this condition. As a rule, no unusual symptoms reveal them-

* "Status Lymphaticus," a clinical lecture, *Lancet*, Aug. 6, 1910.

selves during induction, but these patients appear to have little resistance to the anæsthetic, so that normal quantities and strengths of anæsthetics produce great and even fatal results. It is probable that such children run about the same risk as any other person whose vitality is low and whose circulation is feeble. The state is allied to cretinism and infantilism.

(2) The selection of an unsuitable anæsthetic: *e.g.* (*a*) nitrous oxide gas for a patient with obstructed breathing due to inflammatory swelling, œdema of the larynx, of the pharyngeal structures, or of the deep tissues of the neck; (*b*) ether for a patient whose bronchial tubes and pulmonary alveoli are choked with secretion; (*c*) chloroform for a patient whose heart is beating feebly and blood pressure is markedly low.

(3) Faulty preparation of the patient.* When directions are given about the diet, clothing, and regulation of the patient's bowels, too little attention is often paid to the effects likely to result from the anæsthetic. Weakly subjects, and especially children, are frequently left too long without nutriment, or are allowed indigestible food. Beef-tea, for example, is sometimes ordered to be given at unsuitable times—*e.g.* 5 a.m. or 6 a.m. It is very much better to diet the patient with care for one or two days before the anæsthetic is given. Alcohol given before the anæsthetic is inhaled is always harmful. It is, in my experience, better to rely upon the stimulant action of hot water taken three hours before the operation; it may be flavoured with tea. Rectal feeding is far better for weakly subjects than food taken by the mouth. It can be employed to within an hour or so of the operation. Glucose in warm saline (℥ i. in ℥ vi.) is the best form of rectal feeding, and may be given every four hours.

Weakly patients should not have strong aperients administered on the night before the operation. It is better that such purging as may be required should be done a day or so previous to that on which the anæsthetic is to be inhaled. Even an enema used just before the operation in some patients may produce prostration. An equally important matter is the maintenance at the normal height of the patient's tempera-

* This subject is discussed fully in Chapter II., pp. 24 and 55.

ture, as this lessens shock. Loosely fitting warm clothing should be arranged to cover the chest, abdomen, and limbs. The room in which the operation is performed should be kept at 65° F., or even 70° F.; but thorough ventilation is essential. It is equally necessary to warm the room into which the patient is carried after the completion of the operation. Many cases of collapse attributed to ether bronchitis are really due to the neglect of this precaution. Arrangements for warming the operating table should be made, but every precaution against burning or scorching the skin is imperative.

To anæsthetise a patient in a bed, and then to carry him into another room for the operation, is, I think, a dangerous proceeding. If circumstances exist which render this unavoidable, there must be no rough and unskilful lifting, since these are extremely dangerous. The "head lower than the body" posture **must** be preserved in carrying: jolting and jerking **must** be avoided.

The utmost attention should be paid to the posture of the patient when on the operating table. It is easy to observe or ascertain in what position in bed he lies when breathing with the greatest ease, and this position should be adopted for the patient as far as the requirements of the surgeon permit when the patient is placed upon the operating table. This is especially important in the case of patients suffering from goitre, heart disease, aneurism, empyema, obesity, large abdominal tumours, and in those who are very old or very feeble.

Preparations should be made for possible contingencies. Sterilised tracheotomy instruments should be ready at hand. Cylinders of oxygen must be in the room. Tongue forceps, gags, transfusion apparatus, and warm normal saline or Locke's fluid may all be needed in cases where severe operations are contemplated, or the condition of the patient is critical.

It is often wise, especially in the case of mouth breathers, to place a dental prop between the teeth before administering the anæsthetic. It should, as a matter of course, be secured by fishing-line to another prop attached outside the mouth. Fixing tongue forceps on the tongue as a routine measure is

unnecessary, and causes pain after recovery from the anæsthetic.

Silence and avoidance of all noise during the induction of anæsthesia must be enjoined.

The attention of the anæsthetist should be concentrated on his work and on his patient. However desirous he may be to "lend a hand" as an assistant to the operator, he should resist the temptation and restrict his energies to his peculiar province. He has quite enough to do, and while handling the inhaler he cannot be surgically clean. It is important to see that the apparatus for anæsthesia is properly cleansed before use, and that the agents used are fresh and in their respective bottles and places. If the patient is lifted or moved, the anæsthetist should withdraw the inhaler during the change of posture, and should redouble his vigilance, as many dangers may arise at such a moment—*e.g.* syncope, vomiting.

In this place, I may again caution against giving chloroform in a small room in which illuminating gas or a lamp is burning. The decomposition of the anæsthetic, arising from the burning of its vapour, will be a sure source of danger to the patient and those engaged in the operation.

The use of the actual cautery.—Patients can inhale ether or ethyl chloride before the use of the cautery in their air-passages. If a breath or two of air is allowed before the cautery is applied, there is no danger of the expired air exploding. Dr. Inglis Clark was kind enough to make some careful experiments with ethyl chloride in this connexion, and his results appear to accord with my clinical experience.

Minor complications.—Such troublesome complications as breath-holding, panic, belching, hiccough, pharyngeal cough, and sneezing have been dealt with in preceding chapters. One complication may be mentioned here, *viz.* maniacal excitement during the induction of anæsthesia. Sir F. Hewitt has cited some cases, and I have met with many degrees of this state. As a rule, unless the patient's antecedent history, his habits, and his temperament point to the likelihood of these maniacal seizures, danger is absent. I know of a case in which a dentist had his operating room wrecked by a patient, a military man, and of another in which

an anæsthetist incautiously permitted his patient to get hold of the Clover's inhaler. This he promptly threw through the window. Alcoholics, unless rapidly anæsthetised, become violent.

I. ACCIDENTS CONNECTED WITH RESPIRATION.

Anatomical conditions such as cicatrices dragging down the skin, and so fixing the larynx,* goitres, and intralaryngeal growths, may cause dyspnœa and alarming interference with respiration, as soon as the patient is partly under an anæsthetic. Faulty position of the patient's head may lead to similar accidents. The dropping of the chin upon the breast and the over-extension of the head while the jaw is permitted to fall are examples of faulty posture. Dyspnœa arises when, through spinal disease, the thoracic muscles are paralysed and the respiration is entirely diaphragmatic. As a rule the difficulty in respiration becomes much exaggerated in narcosis.

Foreign bodies may become loose in the mouth, and either get drawn into the larynx and thence into the trachea, or may become impacted, and so set up laryngeal spasm.†

Small plates carrying artificial teeth are especially dangerous, and obturators, pivoted or loose teeth, may also become sources of peril. During an operation teeth, or pieces chipped off teeth, may fall back; and even portions of epitheliomatous or other growth, blood clot, pus from the bursting of post-pharyngeal abscesses, blood from epistaxis, detached tonsils and turbinate bodies which have slipped from the guillotine or turbinotome, nasal polypi, vomited undigested solid food, tobacco plugs, gags, portions of snapped-off forceps, and bits of sponge may obstruct breathing. Profuse salivation associated with increased secretion from the bronchi causes respiratory difficulty, and the patient

* I have met with several such cases, especially troublesome when the mouth and chin are dragged down to the chest, and when the tongue is fixed to the floor of the mouth. Dr. Leonard Guthrie narrates some typical instances in his thoughtful brochure, "Chloroform-Narcosis in Children," p. 53.

† A round worm vomited from the stomach has under an anæsthetic passed into a bronchus and caused asphyxia.

becomes suffocated by his own secretion, unless the gravity of the situation is realised and prompt measures are adopted to remove the danger. When the tongue is partially removed, the stump is liable to fall back and cover the glottis; and similarly, after removal of a portion of the lower jaw, the whole tongue is often carried back by its own weight. This may also occur in deep narcosis, even when the jaw is intact. The fingers inserted in the mouth during tooth extraction often push the tongue back, and complete occlusion of the air-way results unless this is noticed and remedied.

Precautions.—All loose bodies should be removed from the mouth before operation. The anæsthetist should ascertain if the patient has taken any solid food on the day of operation. It is a good rule in dental surgery never to operate upon the second tooth, when extracting several teeth, until the first tooth extracted is known to be *out of the mouth*; and care should be taken that the forceps are freed from the tooth just removed before they are employed again. A Carter's oral spoon (see fig. 12, p. 75) held in the mouth during tooth extraction prevents teeth falling back and being drawn into the larynx. In prolonged operation, when possible the head should be placed on its side, to obviate the weight of the tongue carrying it back; this will also facilitate the expulsion of blood.

Treatment.—In the event of any foreign body becoming loose, the jaws must be separated by a mouth opener, a gag inserted, and the substance sought for with the finger. The patient's head and shoulders should be lowered, and efforts should be made to excite the laryngeal reflex by drawing forward the epiglottis by means of a bent tongue depressor, or forceps. Slapping the back certainly aids. When bronchial secretion is profuse, and when blood, pus, etc., have been aspirated into the trachea, the patient's head is to be turned to the side, and, if a dental prop is not already in position, the mouth must be opened and the pharynx mopped out. When these measures are obviously ineffectual, the patient must be inverted and the secretions allowed to drain out, their passage being assisted by pressure upon the chest. Schäfer's method of artificial respiration is applicable to all such cases (see p. 389).

The following record of cases well illustrates this point :—

(1) The cases cited on p. 125 exemplify this danger and the correct method of treatment.

(2) In this case, the patient, a short-necked, thick-set man, to whom I gave ether for an examination, so much mucus was secreted that respiration was dangerously affected. Inversion and pulling forward the tongue led to the escape of a large quantity of fluid and relief of the dyspnœa.

In the case of a **solid body** entering the air-passages, unless it can be seen and removed by means of forceps, the air-way must be opened and the occluding substance, if possible, removed. In some cases the dyspnœa, which at first threatened life, passes off, owing probably to the position of the foreign body becoming altered. When this happens, it is better to delay surgical proceedings and subsequently perform a formal operation at a suitable time; but, as Sir Rickman Godlee points out, "the inconvenience of an early tracheotomy and the resort to the usual methods of search are not for a moment to be weighed against the possibly irremediable damage that may be done by even a few weeks' residence of a foreign body in a bronchus." *

When teeth, fragments of teeth or of metal stoppings, enter the air-passages, cough of a distressing character is set up. This either increases, and if the cause of obstruction is not expelled the dyspnœa calls for immediate relief by tracheotomy and inversion, or the immediate urgency may pass off. Later on the foreign body may be coughed up, although sometimes it may give rise to an abscess, and be subsequently expectorated; in other cases local septic pneumonia of painful chronicity is developed. Recorded cases have terminated fatally after prolonged illnesses, so that no pains should be spared to avoid this grave complication (see p. 130).

The introduction of the bronchoscope now enables the surgeon to ascertain the precise position of any solid body and to remove it. This is the best method of dealing with such cases after the immediate and urgent dyspnœa has passed off.

Vomited matters.—When, through the exigencies of the

* *Trans. Med. Chir. Soc.*, vol. lxxix., p. 206.

case or inadvertence, food has been taken within a few hours of the administration of an anæsthetic, vomiting is pretty sure to occur, either when the operation is proceeding or as the patient is commencing to regain consciousness. There is great danger lest vomited matters be drawn back into the larynx, leading to asphyxia.* In patients who are necessarily operated upon after having taken food, it is certainly wise to wash out the stomach either before the inhalation or as soon as the patient is sufficiently insensitive to permit the lavage without struggling.

Respiration may also be hampered by—the posture † of the patient, by pressure upon his chest due to assistants leaning upon him, or by tight bandaging. In edentulous persons, especially if nasal stenosis exists, the lips are sucked in during inspiration, and this often causes great respiratory difficulty, cyanosis, and inspiratory dyspnœa. This frequently arises before the patient is fully under the anæsthetic, and prevents his passing completely into the third degree of narcosis. It is at once relieved by inserting a gag, which keeps the lips apart and allows the anæsthetic to be inhaled. When placed prone or upon the side, feeble people, and those who are fat or emphysematous, or who have fluid in their chest—one lung being more or less hampered—must be carefully watched, as the mechanical interference with breathing in these cases has caused fatal accidents. The complication is peculiarly liable to occur in the case of children, and especially in that of **rickety** infants, whose respiration is very commonly feeble. Similarly, respiratory embarrassment may be caused by the “lithotomy” or extreme Trendelenburg position, especially if the patients are fat. Gradually failing

* The following case illustrates this danger: A hospital patient requiring a minor operation was instructed to abstain from food and present himself in the evening for the house surgeon to operate. The operation was performed—the patient being skilfully anæsthetised by a resident house physician; but during recovery he vomited, and large masses of undigested meat were taken from the mouth. Asphyxia being imminent, laryngotomy was performed, but the patient died, and the necropsy showed that a mass of meat had entered the trachea, and lay at its bifurcation, occluding the bronchi. It transpired that the man had, in spite of explicit directions to the contrary, partaken of a heavy meat dinner just before coming to the hospital.

† A useful paper by Sir F. Hewitt and Mr. Sheild may be consulted on the subject of posture under an anæsthetic. See *Trans. Med. Chir. Soc.*, vol. lxxix., p. 1.

respiration, leading ultimately to cessation of breathing and associated with deepening duskiness, may arise from too little air being given or a slightly excessive percentage of anæsthetic. It is not uncommon when such mixtures as the A.C.E. or C.E. are used. To relieve the condition, the inhaler must be withdrawn, the mouth opened, and rhythmic traction made on the tongue (Laborde's method), supplemented by one or more vigorous compressions of the chest. In applying Laborde's method the lower teeth should be covered with some layers of gauze to prevent their tearing the under surface of the tongue. The tongue is drawn well out of the mouth, at the time the inspiratory stage of artificial respiration is in process; during the expiration the tongue is allowed to retract. These measures as a rule suffice for minor degrees of respiratory difficulties under anæsthetics.

In cases of **intestinal obstruction** the operation is an added danger, due to the **regurgitation** of the contents of the stomach and intestines into the mouth, and their subsequent aspiration into the air-passages.* Although this condition was dealt with above in speaking of the best methods of giving the anæsthetic in these cases (see p. 364), it may be well to recur to it here. The welling of fluid from the alimentary canal is not a true vomiting, but is rather of the nature of reversed peristalsis. As soon as the anæsthetic takes effect and lessens the tonicity of the cardiac and pyloric sphincters the intra-abdominal pressure becomes relieved by unloading the intestinal contents upward along the line of least resistance, instead of along its normal route. When this regurgitation occurs, every effort should be made by turning the head to the side to divert the regurgitated fluid away from the air-passages. Lavage, frequently repeated, when practicable, should be performed before the anæsthetic is given. The insertion of a gag between the teeth before giving the anæsthetic is an additional precaution which is useful.

* There is a similar danger while artificial respiration is being performed. Undue pressure made upon the abdominal contents may induce expulsion of the fluids contained in the stomach and intestines, and thus the efforts to produce expiration may pump vomitus into the pharynx, and those of inspiration aspirate it into the air-passages.

Constant swabbing out of the mouth, and syphoning the stomach contents by a rubber tube discharging into a pail help to keep the air-passage clear. As has been pointed out above, the narcosis should not be deep until the abdomen is opened, as it is important that the larynx should maintain its sensitiveness up to this point.

Pus or other fluids expelled from the lungs.

During operations for the relief of pulmonary or hepatic abscess, hydatid cysts, or of empyema, the patient may expectorate or otherwise expel large quantities of pus, blood, or other fluids, daughter cysts, etc., from the seat of disease, and these may, unless care is taken, pass into the lungs, and interfere with respiration. As a rule patients clear their lungs of accumulated secretions in the early morning, and soon after this is the safest time for the anæsthetic. Similarly extensive hæmorrhages from phthisical vomicæ may occur, and lead to intense dyspnœa. Beyond being prepared for such emergencies, and maintaining so slight a narcosis that the patient does not lose his power of coughing up the intruding material, little can be done. Posture is of much importance; the sound lung should be kept uppermost, and the patient turned towards the diseased side. Artificial respiration performed by the usual methods is extremely dangerous in these cases, as it pumps the fluids into the pulmonary lobules, and effectually asphyxiates the patient. The "Schäfer" method, which is described below, is less open to this objection, and may be employed in these cases. Ammonia fumes, perflation with oxygen, aided by compression of the sound side of the chest between the hands, one placed on the back and one in front, offer the best hope of assisting the patient to expel the foreign material from his air-passages.

OVER-DOSE.

All general anæsthetics eventually **paralyse the respiratory centre** in the medulla oblongata, and so cause cessation of breathing; but some act more rapidly, and may induce spasm of the glottis if the vapour is too

strong. When spasm is excited no air enters the lungs, but irregular thoracic movements persist. Spasm of the larynx certainly may occur from ethyl chloride or ethyl bromide, ether, or chloroform vapour, and, it is stated, from nitrous oxide gas. Cases occur in which the patient, either as the result of some pungency of the vapour inhaled, or because some of the anæsthetic vapour having become condensed comes in contact with the laryngeal mucous membrane, coughs with extreme violence, expiration becoming weaker and weaker, and inspiration ceasing. This state culminates in spasm of the glottis, cyanosis, and urgent dyspnœa. Spasm may arise not only from the patient receiving an overstrong vapour, but as a result of gradual asphyxia. The blood becomes imperfectly oxygenated, and breathing is interfered with. The patient's colour will become progressively more and more dusky, the lungs will be imperfectly ventilated, and the right heart over-distended. Spasm then occurs, and the respirations become anarchic and cease, deep cyanosis supervening.

The head must be extended; the tongue seized and drawn rhythmically forward, and pressure made upon the *lower* ribs. Oxygen inhalations will often relieve the spasm, and should be given when the spasm is sufficiently relaxed to permit the gas to be inspired. As a rule the spasm passes off rapidly, being relieved by the admission of air, but it may be sufficiently severe to need laryngotomy. Phosgene gas, the result of the decomposition of chloroform, may cause laryngeal spasm. Chloroform also acts upon the larynx in another way, whereby the air-passage becomes occluded—namely, by the closure of the aryteno-epiglottidean folds (Lister). In this case respiratory movements persist, although no air enters the chest.

Patients may be actually asphyxiated by the administrator excluding all air; and this may occur with any inhaler, unless care is taken, and the colour of the face watched.

The sighing and sobbing breathing of children is prone to lead to over-dosage. Even when the induction of anæsthesia has been normal, gradual over-dosage leading to enfeebled respiration will ensue unless the anæsthetist

regulates the depth of narcosis. The full breathing of the stage of stimulation gradually passes off, the eyeballs under chloroform become fixed, and the conjunctival reflex is lost. Light reflex grows less active, and blood pressure having fallen the pulse is weaker. These signs taken together indicate profound narcosis. It is then necessary to lessen the amount of anæsthetic, and to give air more freely, or even to withhold the anæsthetic altogether for a breath or two. Pallor, fall of blood pressure, halting respiration, with returning conjunctival reflex, and a moving eyeball, associated with swallowing movements indicate lightening narcosis, and the probable supervention of vomiting. In this case unless the patient is very feeble the treatment required is increase of the anæsthetic, always provided that it is known that the stomach is empty. These parallel conditions require great care to avoid making a mistake, since it may be fatal.

Cyanosis which is due to respiratory embarrassment should be watched for, and remedied by giving air or oxygen. Feeble breathers will often become slightly blue even when inhaling low percentages of an anæsthetic. If the respiration is not stimulated by fresh air it will grow weaker, and finally cease, although prompt recourse to artificial respiration will restore it. This increasing enfeeblement of respiration should never be allowed to pass unnoticed or unrelieved.

Patients who are very nervous, especially if they have repeatedly taken anæsthetics, will sometimes voluntarily hold their breath, and may in this way produce serious asphyxial symptoms.

Treatment of conditions causing interference with respiration.—When a foreign body is lying free near the upper opening of the larynx the tongue should not be pulled forward, otherwise the foreign body, especially if it is a tooth lying on the back of the tongue, may enter the trachea, since tongue traction by pulling forward the epiglottis leaves the larynx unprotected. If the foreign body can be felt to be fixed, its removal must be attempted with laryngeal or œsophageal forceps, or with a snare. When the obstruction cannot be reached with the finger the patient should, if conscious, bend with his head very low, breathe air softly,

and expire or cough forcibly while his back is slapped. This often causes the foreign body to be expelled. Failing these measures the patient should be inverted, with the view of dislodging the foreign body, although, of course, this procedure may set up laryngeal spasm due to the foreign body impinging upon the vocal cords from below. When this does not succeed, and if suffocation be imminent, laryngotomy must be performed. When the glottis has become occluded by the *falling back of the tongue*, pushing forward the lower jaw, so that the lower teeth lie in advance of the upper, will, by carrying the base of the tongue and epiglottis forward, open the air-passage. This is best done by pushing the angle of the jaw forward, at the same time depressing the chin to prevent the lower teeth engaging behind the upper ones. Considerable interference with respiration may arise from the lips closing upon the teeth. Inspiration under these circumstances cannot occur, although a certain amount of expiration is carried on. The same obstruction often occurs in edentulous persons, the lips being drawn in and acting like an expiry valve. Nasal stenosis is a common cause of this difficulty, and relief may be obtained by opening the mouth, and inserting a gag between the teeth or gums. There is sometimes spasm of the jaw muscles, especially of the masseters, associated with the condition, and some difficulty may be encountered in the attempt to open the mouth. There is usually a gap in the line of teeth so that a gag can be introduced, and the mouth partly opened. As soon as this is done the tongue can be pulled forward, and the oxygen tube introduced. Since the spasm is really asphyxial it is, as a rule, relieved by such expedients, and the more drastic measure of opening the trachea can be obviated. In persons with thick necks, and in cases of angina Ludovici, the anatomical conditions cause dyspnœa and cyanosis. Such cases should be treated on similar lines, although in the last case laryngotomy may be difficult.

The position in which the head should be placed while these measures are being carried out is of some importance. That which promotes the greatest freedom of breathing is the one which is required, and this varies in individual cases, and can readily be found by changing the pose of the head.



Dr. Benjamin Howard has advocated the method of placing the head in extreme extension in order to obtain the maximum degree of patency of the upper air-passages during narcosis. Professor Wood, however, contends that a better plan is to place the index fingers of each hand on the cornua of the hyoid bone, and the middle fingers against the angles of the jaw. The fingers should press forward and upward, thus extending the head on the neck and so opening the glottis. If this does not succeed, he recommends fixing a tenaculum far back into the base of the tongue and drawing it forward. I have found that lifting the hard palate with the forefinger of the right hand while the tongue is hooked forward with the left forefinger, gives an extremely good air passage.

It should be remembered that when a patient is coming out of chloroform, and is about to vomit, the glottis becomes closed, and this may cause marked cyanosis. However, this state is at once relieved by the act of vomiting, and calls for no special treatment. In delicate subjects it is, however, liable to be associated with marked circulatory depression, in some cases leading to actual syncope.

When **spasm** of the **larynx** results from inhaling an anæsthetic and persists after drawing forward the tongue and hooking up the larynx, laryngotomy must at once be performed. No formal operation is necessary; the crico-thyroid membrane is incised, and a laryngotomy tube inserted. It is suggested by some that inhaling chloroform relaxes the spasm; but this plan is of course useless if the rima is quite occluded, and its adoption may involve loss of valuable time.

Ether inhalation, when the ether vapour is forced upon the patient in too concentrated a state, may set up some **spasm**. This, although, causing alarming dyspnœa, does not as a rule require any heroic treatment. Drawing the lower jaw smartly forward, so that the lower teeth advance beyond the upper, and withdrawal of the vapour, are, as a rule, all that the complication demands. I have met with several cases in which alarming symptoms have followed spasm of the glottis during ether inhalation. It arose, I believe, from condensed vapour impinging upon the vocal cords. Dyspnœa and violent coughing are the symptoms; the patient becomes dusky and

even deeply cyanosed, and no air enters the lungs. This danger arises during the induction period, and can be usually successfully combated by traction on the tongue and oxygen inhalation. I have never been compelled to open the trachea.

If, after the upper air-ways have been cleared and rendered patent by the manœuvres mentioned above, the breathing still remains unsatisfactory, artificial respiration must at once be practised by one of the following methods. There should be no delay in adopting artificial respiration; all other measures are subsidiary, and although these need not be neglected, yet time should never be wasted, but lung ventilation assured. Artificial respiration not only eliminates the anæsthetic vapour from the lungs, but promotes the passage of blood through the pulmonary circulation, and prevents heart-block. Of course, it is essential to ensure (i.) patency of the air-passages, (ii.) the most favourable position of the patient for free respiration, and for improving the blood-flow to the central nervous system.

Artificial respiration.—

I. THE SCHÄFER METHOD.

Sir Edward Schäfer,* who has investigated the relative efficiency of various methods of performing artificial respiration, finds that the following gives the fullest pulmonary ventilation and offers the best chance of ejecting fluids which have entered the lungs. The method cannot be adopted in all cases of suspended respiration under anæsthetics, since it involves placing the patient upon his face. I quote Sir Edward Schäfer's own words to describe the method he has suggested :—

“ To effect artificial respiration, put yourself athwart or on one side of the patient's body in a kneeling posture and facing his head (see fig. 76). Place your hands flat over the lower part of the back (on the lowest ribs), one on each side, and gradually throw the weight of your body forward on to them so as to produce firm pressure—which must not be violent—

* See *Report of Committee Roy. Med. Chir. Soc.*, 1904, vol. lxxxvii.; *Proc. Roy. Soc. Edin.*, vol. xxv., part i., p. 39.

upon the patient's chest. By this means the air (and water, if there is any) is driven out of the patient's lungs. Immediately thereafter raise your body slowly, so as to remove the pressure, but leaving your hands in position. Repeat this forward and backward movement (pressure and relaxation of pressure) every four or five seconds. In other words, sway your body slowly forwards and backwards upon your arms twelve to fifteen times a minute, without any marked pause between the movements. This course must be pursued for at least half an



FIG. 76.—Showing the position to be adopted for effecting artificial respiration (Schäfer's method).

hour, or until the natural respirations are resumed. If they are resumed, and, as sometimes happens, again tend to fail, the process of artificial respiration must be again resorted to as before."

2. SYLVESTER'S METHOD.*

For this method the patient is placed flat upon his back with the head somewhat lower than the abdomen, and care taken that there is no mechanical obstruction to the entrance of air—*e.g.* falling back of the tongue, blood clot, mucus, or vomit in the pharynx.

During the performance of artificial respiration Wilson†

* The method described is modified by the introduction of the essential features of the plans proposed by Pacini and Bain.

† *Trans. Soc. Anæsth.* 1898, vol. i., p. 35.

agrees with Dr. Bowles that it is best not to have the mouth widely open, and the tongue dragged far out of the mouth.

The whole jaw should be pushed forward, the neck being kept fully extended. There should be no strain from the chest, and so the head should not be allowed to hang back over the end of the table. The operator stands behind the patient and grasps the arms *near* the elbows in such a way as to evert them and render the pectorales majores tense. He first presses the arms into the sides, so as to compress the



FIG. 77.—Artificial respiration—Expiration.



FIG. 78.—Artificial respiration—Inspiration.

thorax and expel air,* whilst at the same time an assistant should make pressure upon the abdomen to prevent the increased intra-thoracic pressure from forcing down the diaphragm. Next, he draws the arms away from the sides, everting them and lifting the trunk of the patient as the arms become about 45° beyond a line running through the body axis; finally, he carries the arms up and back to a line parallel with the trunk. He pauses to allow air to rush freely into the lungs, and then brings the arms down to the sides as before. This process he repeats twelve or sixteen

* It is most important in chloroform cases requiring artificial respiration that *expiration* be performed before inspiration, in order that the chloroform-laden air in the lungs be forcibly expelled before fresh air enters.

times in one minute. The way the arms are grasped is important. When they are held *below* the elbows, it is not possible to open out the chest as effectively as when the plan just described is followed.

The diagrams given on p. 391 illustrate this method of inducing artificial respiration.

3. HOWARD'S METHOD

can be usefully employed, in conjunction with Sylvester's. It is also of value when the patient's chest is rigid. Dr. Howard insists strongly upon the full extension of the head on the trunk, so that the air-ways may be thoroughly straightened out. The patient is between the operator's knees. The latter, who faces him, applies his hands so as to grasp the free margin of the thorax, his thumbs resting upon the xyphoid cartilage. The operator presses upwards and inwards towards the diaphragm, gradually bending over the patient, so that all the weight of his body aids in compressing the thorax. After steady pressure for some seconds, with a sudden push up the operator throws himself back, then the resiliency of the chest walls will induce an inspiration. The process is repeated twelve or sixteen times a minute.

4. MARSHALL HALL'S METHOD.

Dr. Bowles, whose valuable researches have made him an authority upon the subject, has pointed out that in all cases when fluid has entered the lungs this method is valuable and superior to the Sylvester method. It is performed as follows: The patient is placed upon his face, his thorax resting upon a folded pillow; pressure is made upon his back to produce expiration; he is then rolled on to his side; the weight is thus taken from his ribs; they rise, and the lungs expand—inspiration; the trunk is then again rolled into the prone posture—expiration. This is repeated slowly about fifteen times in a minute.

In performing artificial respiration, the force used must be carefully regulated, as it is easy to fracture ribs, especially if the patient is old and the ribs are brittle.

When the chest is markedly emphysematous very little alteration in its capacity can be effected by Sylvester's method, and then either Schäfer's or Howard's must be relied upon, since in these the diaphragm is more efficiently brought into play. These systems are also applicable when, as sometimes happens, the patient has lost one or both arms. I have met with most of these complications. Laborde's method of tongue traction (see p. 292) is a valuable adjuvant to these systems of artificial respiration.

Faradisation of the phrenic nerves by poles placed, one on the external border of the sternomastoid muscle, and one on the thoracic attachment of the diaphragm, is regarded by some authorities as of great value. Personally, I consider it inferior to artificial respiration and to be fraught with danger.

FORCED ARTIFICIAL RESPIRATION.

Professor H. C. Wood regards all the methods of artificial respiration mentioned as imperfect and inferior to the following plan*: A pair of bellows has a length of indiarubber tubing attached to it. A face mask and two intubation tubes of different sizes are also in readiness. In the tubing "there should also be set a double tube, with an opening similar to that commonly found in the tracheal cannula of the physiological laboratory, so that the operator can allow the escape of any excess of air thrown in by the bellows." Professor Wood gives the following directions for employing the apparatus: "In using this apparatus, the mask should be first tried, care being exercised to see that the tongue is well drawn forward and held in place by a thread through it, and that the glottis is kept open." If the face-piece does not succeed, intubation should be at once performed. In the use of either the face-piece or of intubation, the lungs should be slowly but thoroughly expanded by each stroke of the bellows. Care must be taken that only sufficient force is used to expand, not to rupture, the air-vesicles. The use of oxygen as the perflating gas greatly enhances the value of the method. The patient's body temperature should be main-

* See "Therapeutics," ninth edition, p. 159, foot-note.

tained. Forced respiration is of especial value for persons with rigid chests. The methods of intra-tracheal insufflation given below are undoubtedly more effectual than Dr. Wood's simple procedure, but as the latter needs no complicated apparatus, it is applicable when an insufflation apparatus is not at hand.

All measures in artificial respiration must be adopted quietly, firmly, and slowly, since crowding, hurry, fuss, and inexperience are very dangerous. Life may be restored after even an hour's artificial respiration. The employment of the faradic current to excite the diaphragm, although formerly much insisted upon, is now generally abandoned.

Insufflation may be conducted by various methods, (1) the best being an apparatus such as that of Dr. Meltzer or one of the intra-tracheal ether insufflators described above (pp. 190 *et seq.*). It can also be effected in the following ways : (2) through a tube passed through the larynx into the trachea (intubation), as in the method of forced respiration detailed above ; (3) by mouth to mouth, an imperfect plan, but one of value when no bellows are at hand, and especially so in the case of children ; (4) through one nostril. Sir Edward Schäfer tells me it is easy to perflate both lungs by means of a nasal catheter and a pair of bellows, and he regards the plan as being of great value.

II. ACCIDENTS CONNECTED WITH THE HEART AND BLOOD-VESSELS.

* The most serious accidents are those connected with the circulatory system.

Faintness or **syncope**, may be caused by fright before anæsthesia is established, may arise as the result of prolonged operations involving shock or profuse hæmorrhage, or may be occasioned by the entrance of air into a vein. The gravity of the accident depends upon the various circumstances: in lesser degrees attention to posture, *i.e.* lowering the head, and the maintenance of respiration will lead to the patient's recovery. An assistant should dash cold water on to the face and over the chest ; but the really serious cases are less

hopeful, since the heart or the controlling nerve centres may have been paralysed by the action of the anæsthetic.

It will be best to describe the causes of circulatory failure in detail, leaving for the moment the question of treatment. Although syncope may occur under any anæsthetic, and has been recorded as taking place under nitrous oxide, ethyl chloride, ethyl bromide, ether, chloroform, and the many mixtures and solutions of these agents, yet the most serious cases are those which arise when chloroform is being inhaled. The symptoms hardly need recapitulation—pallor, loss of colour in the lips, ears, and finger-tips, failure of pulse, dilatation of the pupils, weakening of the respiration, followed rapidly by its cessation. Clinically the respiratory and circulatory failure are associated. The mechanism by which this failure is brought about has been described in the chapter dealing with chloroform; it only remains, therefore, briefly to enumerate the points which will enable the reader to recognise the bearing of the line of treatment suggested. **Even a few inhalations of a strong percentage of chloroform will paralyse the heart**, either by exciting vagal inhibition or by direct action upon the heart muscle (Embley and Martin; Sherrington and Sowton). When respiration is interfered with, through whatever cause, the heart's action is hampered, the nervous control is seriously threatened, and even small quantities of chloroform may lead to serious or even fatal complications. Under any percentage of chloroform the blood pressure falls. Its fall is gradual so long as respiration is unaffected and no intercurrent complications such as hæmorrhage or asphyxia occur. In prolonged operations, especially if the anæsthetic has been given at all freely, this fall of blood pressure becomes more serious, and syncope may supervene. The appearance of the patient is typical: he becomes pale and slightly dusky; the pallor is best seen in the ears, lips, and beneath the nails; breathing becomes slow and shallow, the eyeballs are fixed, and the light reflex is sluggish or absent; the pupils tend to dilate. Unless the condition is relieved cyanosis rapidly appears, breathing ceases or is represented by a few ineffectual gasps; the radial pulse is lost, but faint heart movements can be felt and heard by auscultation. A sudden fall of blood pressure may occur

quite early in narcosis, especially in young delicate children. It seems to be due, either to their inhaling an unduly strong percentage, or to the onset of vomiting. Even if the last cause is the occasion of the pallor, it is unwise to push the anæsthetic, as children in this condition are easily over-dosed.

In combating the dangers of the fall of blood pressure it is most important to bear in mind the condition of the patient's organs at the time of inhalation. If, for example, the heart is fatty and its action feeble, if the respiration is hampered by old-standing lung-disease or pulmonary œdema, the risk of even a slight fall of blood pressure is enhanced, and it is necessary to restrict the percentage of chloroform from the outset of the administration. The most dangerous period of narcosis, as far as the circulation is concerned, is the induction. Struggling, so common in this stage, at once hampers respiration, interferes with the action of the heart, and leads to an irregular intake of chloroform. Holding the breath produces like results; as a consequence a vicious circle is engendered, the heart fails to empty itself, and the respiration is inadequate so that accumulation of chloroform occurs in the blood stream, while, owing to the increased venosity of the blood, the necessary elimination of the anæsthetic from the tissues cannot occur.

Although **diseased conditions of the heart and blood-vessels** as such seldom, if ever, constitute an insuperable objection to the giving of a general anæsthetic they may produce dangers. A feebly beating fatty heart, and a dilated heart without compensation, are liable to become exhausted and to fail if over-stimulated. I regard this danger as even greater than that arising from depression, always provided the blood pressure is maintained. If this last condition ensues from giving an excessive strength vapour of chloroform or ethyl chloride, the anæmia of the medullary centres, and failure of the coronary circulation will cause syncope, and **inversion with artificial respiration** is called for. If, on the other hand, excessive stimulation has been practised the heart will stop and there is little hope of recovery. In the same way struggling and acapnic conditions will lead to heart failure. The employment of oxygen associated with carbon dioxide has been suggested by Dr. Yandell Henderson and Dr. Levi

(Florence), and may prove of value in such cases, although heart massage (see below) offers the best hope of saving the patient.

Aneurism.—In what I believe to be a unique case* an aneurism burst into the pericardium during anæsthesia, and mechanically produced heart stop. If heart massage had been attempted it seems probable that the condition, which otherwise could hardly have been recognised, might have been detected and possibly relieved by surgical procedure.

Again, in diseased conditions of the arteries two main dangers arise. In cases of excessive blood pressure due in part to arterio-sclerosis, and in part to stimulation by the anæsthetic, possibly associated with struggling, rupture of one of the arteries of the brain may occur. This accident has been reported with nitrous oxide, with ether, and ethyl chloride, and may prove fatal. The treatment can only be conducted upon general principles, although bearing the danger in mind, prophylaxis, *i.e.* avoidance of struggling, asphyxial complication, and of excessive stimulation, may prevent a danger which can hardly be remedied. The second danger arises from the detachment of clot from the sac of an aneurism and consequent embolism and infarction. I have repeatedly administered an anæsthetic to persons who suffered from aneurism, and have only once met with this accident. In this case the anæsthetic used was ether, which I now consider to be not a generally suitable choice, and the sac of the popliteal aneurism filled with clot and so was spontaneously cured. No ulterior dangers occurred. In phlebitis and "white leg" there is a similar danger, and here again prophylaxis, rather than subsequent treatment, is the best protection of the patient's life.

Treatment of circulatory feebleness.—This necessarily varies, according as the patient is suffering from a slight fall of blood pressure, or has inhaled an over-dose of the anæsthetic. If the condition is mere faintness, cease the anæsthetic, lower the head, apply nitrite of amyl or ammonia fumes to the nostrils. The ammonia, if too strong, causes spasm of the glottis; smelling salts, if at hand, will give the required stimulus to breathing. The chest may be compressed by the

* *Trans. Soc. Anæsth.*, vol. ix., p. 6, Dr. A. M. H. Gray's case.

hand, and oxygen given by inhalation, but the tube must be held over the glottis. The patient should be placed supine, his legs and arms raised, and his head dropped below the level of the trunk, partial or complete inversion being of the greatest value in syncope during narcosis. The maintenance of regular respiration is of the greatest importance in all cases of syncopal seizure, and to this end artificial respiration must be practised at once. Rubbing the inside of the lips with brandy is of marked value in these cases. An enema of brandy— $\mathfrak{z}$ ss. in $\mathfrak{z}$ ij. of hot beef-tea or gruel or starch—may be tried. When the patient has recovered sufficiently to swallow, hot strong coffee with a teaspoonful of cognac should be given. The most stringent injunctions must be given that the horizontal posture be maintained until the heart has quite recovered itself. Many authorities advise the injection of Liq., strychninæ, $\mathfrak{m}$ iv. or $\mathfrak{m}$ v. being introduced under the skin, and this procedure is of value when respiration is feeble and operation shock is not the cause of the fall of blood pressure.

In graver cases.—When the above symptoms do not yield to such treatment, or if the condition of the patient is obviously very serious *ab initio*, complete inversion with vigorous artificial respiration, or, still better, forced respiration (intra-tracheal insufflation) with oxygen must be adopted. Bandaging the abdomen is certainly valuable, and should be adopted when the blood pressure has fallen. Rectal injections of hot water or saline are of undoubted utility. The treatment rehearsed above also applies to these cases; in them it is usually more common to find a *gradual heart failure* occurring, and giving warning of trouble. Respiration also is liable to flag at the same time as the heart fails. It is especially necessary, therefore, to have resort to artificial respiration early, both on this account and because that measure even by itself will frequently steady the heart and restore its rhythm. Maas's method of rapid percussion over the cardiac area has been already noticed. Although artificial respiration with inversion and the direct action of kneading the heart by cardiac massage are the really important procedures, efforts may be made to assist circulation by various subsidiary means. Of these, hypodermic injections of

such drugs as strychnine, pituitary extract, and digitaline are in common use. Strychnine in gr. $\frac{1}{30}$ doses is of some value in respiratory depression with general circulatory feebleness, but should be avoided when there is reason to believe that the nerve controls are exhausted. The pituitary extracts* are the most powerful vaso-motor constrictors, and, although their effect soon wears off, are of undoubted value. Hypodermic injection of sparteine sulphate gr. $\frac{1}{2}$, or oxysparteine (Langlois and Maurange) is of service in averting heart failure under chloroform. Transfusion of normal saline has been used successfully in cases of syncope associated with severe hæmorrhage under anæsthetics. The saline solution may be introduced directly into a vein, or infiltrated through a cannula into the cutaneous tissues of the thigh or arm. The use of intra-venous infusion of saline is, I think, the most valuable of all the subsidiary means of treating collapse due to shock under anæsthetics when this is not due to over-dosage.

Acupuncture of the heart.†—In a series of careful experiments Dr. B. A. Watson has shown the utility of puncturing the right ventricle in cases of heart failure under chloroform. It is possible by this plan to remove the excess of blood from the overtaxed heart at the same time that a mechanical stimulus is applied to the myocardium. The plan has been tried in the case of human beings, but I believe without conspicuous success.

DIRECT MASSAGE OF THE HEART.

The heart muscle may not respond to puncture, but it is well known that, when subjected to direct manual manipulation, it is capable of expelling its contents and resuming its normal rhythm. Guided by this physiological fact, Prus ‡

* The dose of pituitary extract (infundibular) is 0.5 to 1.0 c.c. of 20 per cent. extract, representing 0.1 to 0.2 gm. fresh infundibulum given intra-muscularly to avoid superficial sloughing from local vaso-constriction (Martindale). The Vaporo-le pituitary of Messrs. Burroughs & Wellcome contains 0.5 to 1.0 c.c. of the posterior cornu while their tabloid of pituitary gland contains 2 grains.

† See a useful paper by Dr. B. A. Watson, *Trans. of Amer. Surg. Assn.*, May 13, 1887.

‡ *Hospitalstidende*, 4 Roekke, Band viii., No. 47, R. Kier-Peterson.

originally suggested a plan by which the surgeon could gain access to the heart, in cases of cardioparesis under anæsthetics, and excite it to renewed activity. His operation, which involved a formal and prolonged surgical procedure upon the thorax giving access to the pericardium by resection of portions of the third and fourth ribs, has been superseded by simpler methods. Dr. Babcock's method has been already described (p. 293).

When the abdomen is not the seat of operation, the above method can be adopted, or the abdominal parietes can be rapidly divided, and the hand introduced. The heart is then grasped between the finger and thumb and slowly compressed. The suggestion that the diaphragm should be divided to render this manœuvre more effectual involves additional risk, and does not seem to increase the efficacy of the method. In most instances, as in the case reported by Dr. Starling and Mr. Lane,* the operation being an abdominal section, there is no delay in thus gaining access to the heart. Professor Keen collected a number of cases, but the conclusion he came to was far less hopeful than that which more recent statistics have justified. If adopted early in the course of resuscitative attempts, direct rhythmic compression of the heart alone, or coupled with acupuncture and withdrawal of blood, would seem to offer more hope of success than other procedures. Since Professor Keen's paper a large number of cases have been dealt with in this way, and the successes have been so numerous as to be encouraging. Dr. T. A. Green† and Dr. V. Orr‡ have collected cases and reviewed this subject. The delay in adopting heart massage is probably the most potent cause of failure. When the abdomen has been opened for the purposes of the operation there can be no reasonable cause for hesitation, provided the respiration is maintained by insufflation, perfusion, or other methods. The heart should be grasped through the diaphragm and kneaded between the fingers and thumb from fifty to seventy times a minute. It is best to avoid extreme pressure at first and undue

* *Trans. Soc. Anæsth.*, vol. vi., p. xxvii.

† *Lancet*, Dec. 22, 1906.

‡ *Trans. Roy. Soc. Med.*, Section of Anæsthetics, Nov. 5, 1909.

rapidity, and it is important to recognise spontaneous beats so as to knead in their rhythm.

After effects occurring in the post-anæsthetic stage.—

These may arise as the result of faulty position, collapse from shock, and chilling of the body when the patient is carried from a hot operating room into a fireless bedroom.

Faintness and vomiting are dangerous in the case of a very asthenic patient, and may arise through a faulty posture, or if he is placed in such a position that he can roll upon his face. There should always be an attendant to turn the head (it is not necessary to raise it) when vomiting occurs, to prevent vomit being aspirated into the air-passages.

Collapse is best treated by heat applied to the patient's body, great care being taken that the hot-water bottles do not cause burns. When morphine has been given immediately before the operation or at its close, and before the anæsthetic stage has passed off, there is a danger of the development of deepening coma, enfeeblement of respiration, and circulatory depression.

Many have observed that in some cases patients, who were apparently suffering but slightly from shock and in a light degree of narcosis at the close of a prolonged operation, became progressively more collapsed and profoundly unconscious within a short time. Their breathing became feeble, the pulse weak, and the skin cold; these symptoms may arise from surgical shock, but are as a rule due to unnecessary quantities of the anæsthetic having been inhaled and the incautious use of morphine after chloroform. One of the dangers of ether arises from the collapse which is apt to follow its stimulating effect pursued throughout a protracted operation.

When the amount of anæsthetic has been carefully kept within the narrowest limits of the surgeon's requirements, and the strength of vapour employed has been also kept low, very little anæsthetic shock arises. It must be remembered that shock due to surgical procedures is evinced by fall of body temperature, declension of the blood pressure and exhaustion of the central nervous controls. Those who adopt the acapnic theory add to these the lowering of the carbon dioxide content of the blood. When hæmorrhage occurs,

when the blood pressure is low, and when lung ventilation is diminished and so some asphyxia is present, very much less of an anæsthetic will maintain complete anæsthesia than is necessary when these phenomena are absent. Hence as an operation progresses collapse and other accidents must be prevented by gradual lessening of the anæsthetic. That oxygen lessens shock and is altogether beneficial I have no doubt. Those who deny this and even state that it is harmful have adduced no experimental or clinical evidence of any value to support their *ipse dixit*. *A priori* arguments as against experimental research cannot be accepted.

Occasionally patients, especially after ether, become maniacal and require control. Maniacal seizures may follow the use of any anæsthetic, and indeed have ensued upon the use of analgesics, although they are rare. Usually the persons who are prone to them have a history of being insane or extremely neurotic earlier in life. In the case of alcoholics such seizures seem to be of the nature of delirium tremens. I have given anæsthetics to a large number of persons whose minds were unhinged or who had been lunatics at some period of their life, but I have never met with true mania as a sequela. Sir George Savage's views are that there is a distinct danger of recrudescence of mental trouble after an anæsthetic in the case of those who are pre-disposed to mental aberration.

Paralysis following anæsthesia.—Both central and peripheral paralysis may follow anæsthesia. The central form is due to rupture or blocking of blood-vessels, the result of alterations of blood pressure caused by anæsthetics. Thus **apoplexy**—a rare accident—has been recorded. Beyond attention to the posture of the patient, little can be done in such cases. The choice of the anæsthetic and method of administration should be guided by the necessity for avoiding struggling and an increase of blood pressure, and to ensure absolute freedom from asphyxial complication. These ends are best attained by using chloroform with oxygen from a Vernon Harcourt inhaler. Erb and others have pointed out that peripheral paralyses follow the use of anæsthetics and are usually due to traumatism from pressure on nerves—for example, when the arm is allowed to hang over the side

of the operating table and the musculo-spiral nerve is compressed. Lateral decubitus has led to paresis in the arm upon which the weight of the body rests. The pressure of Clover's crutch also has, it is stated, caused paresis of the nerves of the leg and even damage to the popliteal vessels. Even the forcible extension of the arms upward may injure the brachial plexus. Functional paralysis also may follow anæsthesia. In all the above cases care in avoiding pressure upon nerves is the important matter : after-treatment may be carried out on general principles.

Glycosuria : diabetic coma.—Diabetics must always run an increased risk in taking an anæsthetic. The amount of sugar should be lessened by rest and treatment before the inhalation, and chloroform should be selected and exhibited with oxygen from a regulating inhaler, and every effort made to limit the amount given. I am inclined to think that excessive stress has been laid upon this danger in the case of general anæsthetics. It is largely a question of the amount of the anæsthetic employed and may follow both chloroform and ether. It has also followed spinal analgesia.

Acidosis (post-anæsthetic chloroform poisoning) is considered above (p. 298).

CHAPTER XI.

LOCAL ANALGESIA—SPINAL ANALGESIA.

LOCAL analgesia, that is, loss of sensation to painful stimuli, without the superinduction of unconsciousness, is obtained in the following ways :

1. By painting the skin or mucous membranes with solutions of the analgesic.
2. Injecting such solutions endermically, or hypodermically.
3. Injecting solutions across, or in the course of nerve trunks (conduction or regional), or into the sheath of the nerve trunk (neural).
4. Injecting into the subdural space or into the spinal theca (spinal analgesia).
5. By cold.
6. By electricity.

The application of solutions of analgesics by brushing, or by pledgets soaked in them to the area of operation is unsatisfactory so far as the skin is concerned, but absorption readily takes place by mucous or serous surfaces. Hence in ophthalmology, in laryngology, in rhinology, and in urinology such procedures are commonly employed.

The rapid progress which has been made in local analgesia is largely due to Dr. Heinrich Braun (Zwickau), who, employing solutions of analgesics with supra-renal extracts (adrenine), has demonstrated that the method is of very wide application.

Professor Schleich undertook the pioneer work. As soon as cocaine was shown to be dangerous owing to its toxicity, he evolved the infiltration method, whereby a highly diluted solution was introduced, first into, and subsequently beneath the skin, an artificial œdema being produced. The

obvious drawbacks to this led to the adoption of the present system, in which the area of operation is isolated from the central nervous system by injections of an analgesic around the area, thus blocking the nerve supply in the field of operation ; or by injections made at some distance from the operation site into or about the nerve trunks, which are known to innervate the structures involved. The addition of adrenine* leads to ischæmia, so that the analgesic introduced remains in the neighbourhood of the injection, and so the analgesic effect is increased and persists. Bier and others have, in the case of the digits, toes, and limbs, still further prevented this deportation by using constricting bands on the central side of the operation area. Bier has also suggested injections into veins in this isolated site in order to bring the anæsthetic or analgesic into the most intimate relation with the nerves. This procedure, and the more dangerous one of intra-arterial injection, are too complex to warrant their inclusion in this place ; nor is it necessary, since with regional analgesia the same results are obtainable by less complicated methods.

Since regional analgesia implies the cutting off of a given area from the central nervous system, it is obvious that injections made either extra-durally or intra-durally about the sensory nerve roots of the spinal cord are really an extension of a common method, *i.e.* of regional analgesia. The results of extra-dural injections do not at the present time appear to compare favourably with those made directly into the theca, although M. Tuffier regards the method as of some value. It is proposed to restrict the scope of the present chapter to infiltration analgesia, regional (conduction) and spinal analgesia.

The essence of success in applying these methods consists in an exact knowledge of the behaviour of the drugs which are employed. These drugs may be now considered.

The doses given in the following sections are applicable only to adults.

* Some confusion is liable to arise owing to the number of names given to the adrenal extracts. The term adrenine is employed in this chapter to cover both the preparations from the fresh glands and the synthetic product suprarenine, which appears to be the most stable and reliable agent.

COCAINE.

Cocaine, $C_{17}H_{21}NO_4$, is an alkaloid occurring in the leaves of *Erythroxylon Coca*, and its varieties. Gardeke isolated the principle in 1855, and Karl Koller introduced its use into surgery in 1884. Cocaine is only slightly soluble in water (about 1 in 1,300), but cocaine hydrochloride, $C_{17}H_{21}NO_4HCl$, is freely soluble (2 in 1), and it is this salt which is commonly used for aqueous solutions. The solutions should be made at the time of use. They cannot be boiled, since this destroys their analgesic properties. Many synthetic substitutes for cocaine have been suggested for use as local analgesics. They are known by the trade names of eucaine, alypin, stovaine, anæsthesin, novocain, nirvanin, acoine, new orthoform, and holocaine. The most important of these are considered below.

Cocaine acts as a general anæsthetic when very large doses are taken. Its true action is analgesic, due not to the vaso-motor constriction which it establishes, but to its influence upon the sensory nerve endings. If an area is rendered anæmic and analgesic by cocaine, the subsequent injection of pilocarpine will abrogate the anæmia, while the analgesia remains unaffected. Arloing has shown the same thing by dividing the sympathetic of a rabbit on one side, the animal having been previously cocainised — hypervascularity could thus be seen to exist simultaneously with analgesia.

PHYSIOLOGICAL ACTION OF COCAINE.

In cold-blooded animals, cocaine, whether applied to the heart itself, circulated through the detached ventricle, or injected into the circulation, slows the rhythm and depresses the beat, and finally arrests the heart in diastole. Its depressant action upon the heart is shown by the accompanying cardiogram (taken by the author with Roy's tonometer) (fig. 79).

Cocaine also interferes with cardiac innervation, decreasing in a very marked degree the excitability of the nerves; it abolishes "make" contractions, but "break" contractions

persist. Although both auricles and ventricles are influenced, the latter are more interfered with, and cease to beat before auricular rhythm is arrested (Van Anrep).

The blood-vessels are but little if at all affected by cocaine, unless it be applied locally as a paint, and in this case it is doubtful how far the action is really characteristic of the drug.

In **warm-blooded** animals, an initial increase in rapidity of the heart's beat occurs, the heart's action is weakened, but usually recovers and is said to survive the cessation of respiration (Van Anrep). Vagal inhibition is also much depressed and even lost; blood pressure is greatly lowered, although this is preceded by an initial and transient rise of pressure.

Cocaine produces a very marked **depressing action** upon the **human heart**. Many persons, after even small doses, become pallid and complain of extreme faintness, while the heart's beat grows weak and irregular, the radial pulse becoming almost imperceptible. Cocaine in very large doses (and we must remember that what constitutes a large dose varies greatly among different individuals) renders the respirations more rapid, irregular and shallow, and finally asphyxiates by respiratory paralysis. In human beings, marked dyspnoea and breathlessness may follow its use.

Convulsions and epileptiform seizures, due, it is said (Dürdufi), to vaso-motor irritation producing anæmia of the brain, occur after toxic doses. Death, according to Mosso, results from tetanic contraction of the diaphragm.

The nervous system is much affected by cocaine. The peripheral nerves of sense become anæsthetic over the area into which cocaine has been injected, the analgesia extending just so far as the drug traverses the tissues. When injected into a nerve trunk, it blocks the transmission of impulses. The insensibility wears off in time, and is followed by more or less severe "reactionary pain" (Struthers). When injected into the subarachnoid space analgesia of the lower extremities is produced, but is often associated with severe cephalagia, and sometimes fatal results. Dastre very aptly terms cocaine the "curare" of the sense nerves. Painting over the skin produces no analgesic effect, but mucous mem-

branes absorb the drug, analgesia resulting. The motor nerves are usually only affected by large doses of the drug, but in some persons comparatively small doses have induced paresis or paralysis, lasting for hours or even days. Ptyalism occurs, leading to dryness of the mouth and fauces. Peristalsis is increased and vomiting and borborygmi follow its use. The other secretions of the alimentary tract are lessened. The urea and phosphoric acid excretion is increased by it (Fleischer). Cocaine promotes destruction of tissue and by a constant repetition of this process leads finally to physiological ruin. Mydriasis and proptosis, in warm-blooded animals, follow its use. Cocaine causes also great hyperexcitation of the muscular system and marked agitation; a large dose at first may simulate strychnine in its action, by producing muscular tremblings, convulsive movements and spasms.

Although the mind at first remains clear, there is usually a tendency to garrulity, followed by great anxiety and feelings of unaccountable distress. Langour, muscular weakness, and lassitude will then take possession of the patient, who becomes haunted by most fantastic hallucinations. Some persons simply experience slight elation, or it may be drowsiness, but loquacity is the most usual symptom.

Cocaine would appear to produce an hyperexcitability of the spinal cord, evincing itself in muscular tremblings. The effect on the nervous system may be summed up in the words of Dastre, that while the drug paralyses the terminations of the sensory nerves, it excites initially all other parts—nerve trunks, spinal cord, medulla, encephalon, and the sympathetic chain.

Cocaine produces at first a slight rise in body temperature.

It is eliminated by the kidneys, and often produces albuminuria, or glycosuria, which Van Anrep regards to be the result of the partial paralysis of respiration.

The symptoms which characterise poisoning by cocaine are (1) more or less heart failure with a remarkable lowering of blood pressure, paling of the skin and mucous membranes; (2) great dyspnœic distress from failure of respiration; (3) impairment of mental faculties and even unconsciousness, or in some cases catalepsy or convulsions,

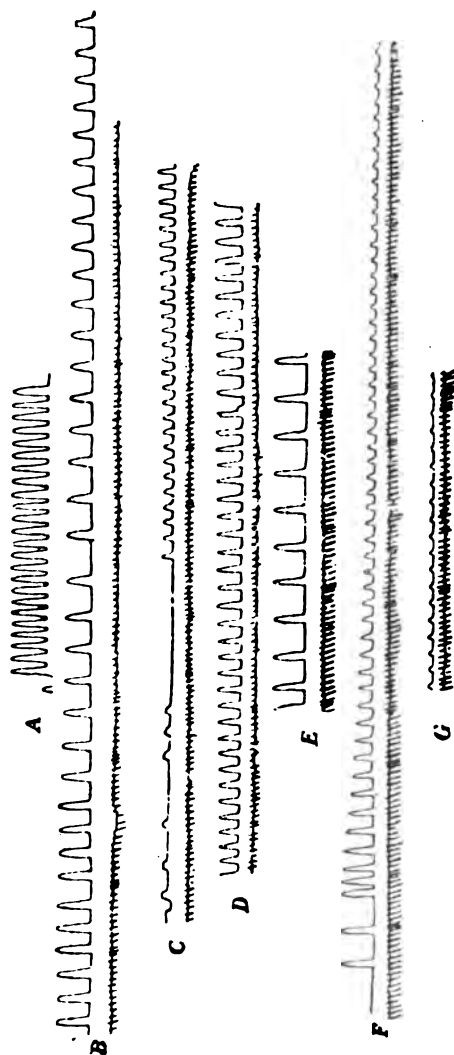


FIG. 79.—Cardiograms of frog's heart (effect of cocaine). *A*. Normal trace. *B*. After addition of cocaine to circulating fluid. *C*. Cocaine removed, nutrient fluid recirculated. *D*, *E*. Recovery to normal. *F*. Cocaine again circulated. *G*. Extreme heart failure, no recovery. Taken with a Roy's tonometer.

or a loss of movement in various groups of muscles. Perhaps the most serious danger of cocaine is its liability to induce a drug habit. Those who have had cocaine injected or even applied to mucous membranes, experience a feeling of pleasant exhilaration, and soon learn to repeat the application in order to renew the sensations.

THE DOSE OF COCAINE.

This depends upon the concentration of the solution used, since, when much diluted, large doses of cocaine are more readily borne and when adrenine is added the toxicity of cocaine appears to be decreased. Reclus gives 0.097 grm. as the maximum in a 1 per cent. solution, 0.194 grm. in a 0.5 per cent. solution; but this is probably too high an estimate. Braun limits the 1 per cent. solution to 0.0485 grm. and the 0.1 per cent. solution to 0.065 grm. Struthers regards 0.065 grm. as the limit in 0.5 per cent. solutions, and 0.13 grm. in the 0.1 per cent. solution when adrenine is added to these solutions.

β -EUCAINE.

β -Eucaine, $C_{18}H_{21}NO_2$, is a synthetic compound chemically allied to cocaine. The best known salts of the base are the hydrochloride and the lactate. β -Eucaine hydrochloride is a white crystalline powder, neutral or very feebly alkaline, and soluble in water 1 in 30. β -Eucaine lactate is soluble in water 1 in 5, and for this reason it has largely superseded the hydrochloride. The proportion of β -eucaine in the lactate is less than in the hydrochloride; 100 grammes of the hydrochloride contain as much of the base as 119 grammes of the lactate. Solutions of the β -eucaine salts may be sterilised by boiling without decomposition.

α -Eucaine, $C_{19}H_{27}NO_2$, differs from β -eucaine in constitution and is no longer used as an analgesic, since its solutions are somewhat painful and irritant when injected.

β -Eucaine solutions are used to produce local analgesia by infiltration with or without the addition of adrenine. A

0·2 per cent. solution is commonly employed for this purpose ; it is made isotonic by the addition of sodium chloride.

Solutions made according to the following formulæ are exactly isotonic.

- | | | |
|-----|--|-------------|
| I. | β -Eucaine Hydrochloride | 0·20 grm. |
| | Sodium Chloride | 0·82 grm. |
| | Distilled water sufficient to make | 100·00 c.c. |
| II. | β -Eucaine Lactate | 0·20 grm. |
| | Sodium Chloride | 0·87 grm. |
| | Distilled water sufficient to make | 100·00 c.c. |

For every 100 c.c. of β -eucaine solution, 10 minims of adrenine solution (1 in 1,000) are generally used, and it is advisable to add this *after* the solution has been boiled. β -Eucaine solutions should always be boiled in Jena or other alkali-free glass vessels.

β -Eucaine resembles cocaine in its general behaviour. It is less toxic, and its action upon the heart is less depressant. It is a vaso-dilator, and diffuses less readily than cocaine. This drug has lost much of its popularity since the introduction of novocain. Although less toxic than cocaine, it is by no means free from danger unless used in very dilute solutions. According to Braun its action is weaker and is slower than that of cocaine or tropacocaine when introduced around nerve trunks, but quite as powerful when it is employed by intra-neural injection. Since it diffuses much less readily than does cocaine, it is less advantageous for infiltration analgesia, and this is true even when adrenine is present in the solution, as this addition rather accentuates the difference between β -eucaine and cocaine.

Poisoning by β -eucaine presents symptoms similar to those of over-dosage by cocaine. Dose 0·097 grm to 0·13 grm., if used in a 0·5 per cent. solution, but as much as 0·389 grm. may be used with a 0·1 per cent.

STOVAINE.

Stovaine, $C_{14} H_{11} NO_2$, HCl, is the hydrochloride of a synthetic compound and is extensively used for producing

spinal analgesia. It is also known as amylocaine hydrochloride, and occurs as a white crystalline powder, soluble in water, 1 in 14.

STOVAINE SOLUTIONS FOR INTRA-DURAL INJECTION.

A 5 per cent., weight in weight, solution of stovaine has the same osmotic pressure as the cerebro-spinal fluid, but since it is desirable to localise the action of the stovaine injected into the canal to some particular region of the spinal cord, some other substance must be added to the stovaine solution to increase its specific gravity.

BARKER'S STOVAINE-GLUCOSE SOLUTION.

This is a solution containing 5 grammes of stovaine and 5 grammes of Merck's pure glucose in 90 grammes of distilled water. The solution has a specific gravity of 1·024 as compared to 1·007 the sp. gr. of cerebro-spinal fluid at 15·5° C. Glucose, while increasing the sp. gr. of the stovaine solution, renders it to a small extent viscid, and thereby diminishes the diffusibility of the liquid.

Theoretically, dextrin is better than glucose, since it is a colloid substance possessing a negligible osmotic pressure, and therefore a very low diffusibility, while it serves to increase the specific gravity equally with glucose. It is convenient to keep the stovaine solution in sealed ampoules of Jena glass each containing about 2 c.c. Since Barker's solution is a 5 per cent. one, each cubic centimetre will contain 5 centigrammes of stovaine.

Stovaine is an antiseptic salt and requires only to be dissolved in a sterile glucose or dextrin solution. It is better to avoid boiling the stovaine. Stovaine is the hydrochloride of a base and its solutions are easily decomposed if they are heated in glass beakers or stored in glass ampoules made of soft soda glass containing excess of alkali, the base being precipitated from the solution in oily drops by the alkali which dissolves out of the glass.

It was first made by Fourneau. The employment of this drug for local and intra-dural analgesia has been introduced

by Pouchet, Tuffier, and employed largely abroad, and has been used in this country by Barker. Stovaine is reputed to possess bactericidal powers, and according to Professor Pouchet it is a cardio-excitant. Its use in local analgesia is less reliable than that of other drugs, but the experience which has been gained shows that it is satisfactory in spinal analgesia. It is stated to be less powerful than β -eucaine in local analgesia. It is used in 0.5 per cent. or 1 per cent. solutions for this purpose, the maximum dose being 0.13 gm. It has been extensively used for intra-dural injection, the maximum dose being 0.065 gm. to 0.07575 gm. Bier combines stovaine with adrenine for spinal analgesia, but Barker deprecates this addition. As indicated above he uses a stovaine glucose solution alone, and gives 0.04859 gm. as an average dose. Th. Jonnesco* of Bucharest states that by adding small quantities of strychnine to the stovaine solution the paralyzing effect of the latter upon the medulla oblongata is counteracted so that high intra-dural injections can be safely performed. These views are, however, not generally accepted in this country, and the high puncture is regarded as too dangerous to be recommended or practised.

NOVOCAIN.

Novocain, $C_{13}H_{20}N_2O_2$, HCl, is the hydrochloride of a synthetic base. It is a colourless crystalline salt, very soluble in water, 1 in 1. Solutions have been used for spinal as well as for infiltration analgesia, and for the nerve trunks (regional analgesia). A 5.07 per cent. solution (weight in weight) has the same osmotic pressure as the blood serum, hence it is necessary to add sodium chloride to the solutions in general use in order to make them isotonic.

The following solutions are isotonic, and they may be sterilised by boiling without decomposition :

A. 0.25 per cent. Solution.

Novocain	0.25 gm.
Sodium Chloride	0.87 gm.
Distilled water sufficient to make	100 c.c.

* *Deutsche medicin. Wochenschrift*, 1909, No. 49, p. 2155.

B. 0·5 per cent. Solution.

Novocain	0·50 grm.
Sodium Chloride	0·82 grm.
Distilled water sufficient to make . .	100 c.c.

C. 2 per cent. Solution.

Novocain	2·0 grm.
Sodium Chloride	0·5 grm.
Distilled water sufficient to make . .	100 c.c.

PROPERTIES AND DOSE.

It is claimed for novocain that it has a low degree of **toxicity**, being one-seventh as dangerous as cocaine, and is non-irritant to the tissues. It is compatible with **adrenine**, and is usually employed with it for local or regional analgesia; while, according to Braun, it is equivalent to cocaine in diffusive power, in intensity, and gives an equal duration of analgesia. It is a neutral compound and is not broken up by the alkaline cerebro-spinal fluid as is to some small extent stovaine. It is employed in 0·5 per cent., 1 per cent., and 2 per cent. for local, and in 5 per cent. solutions for spinal analgesia. Many workers regard 5 per cent. as unduly concentrated, and use 1 per cent. in the spinal canal (Hofmann). In all cases the solution should contain adrenine and be made isotonic by sodium chloride. The maximum dose is 0·75 gramme. Paralysis of the external rectus m. has been recorded after the use of novocain in a few cases of lumbar puncture as also when stovaine has been used. Solutions of 0·4 per cent. may be employed for local infiltration, but 2 per cent. or even 3 per cent. is required for blocking the conduction of large nerve trunks (regional analgesia). Comparing novocain with stovaine, Professor Dixon states that the former is less toxic and less irritant, but weight for weight shows less marked analgesic properties. "Nevertheless," he adds, "the specific action of stovaine on nerve fibres is less than that of novocain, since stovaine destroys other tissues besides nerve fibres."

ALYPIN.

Alypin, $C_{16}H_{28}N_2O_2 \cdot HCl$, is the dimethylamine derivative of stovaine. It is a white, odourless, crystalline powder, very soluble in water, 1 in 1.

Solutions of alypin may be sterilised by boiling without impairing their analgesic action. It is stated to be one of the less toxic of the more commonly used analgesics. In ophthalmic surgery, Landolt points out that it acts as powerfully as cocaine, although more slowly, and is indicated in all operations on the eye when dilatation of the pupil is undesirable, since alypin has no mydriatic power. A 2 per cent. to 3 per cent. solution is used for this purpose. When injected, 3 to 6 c.c. of a 1 per cent. sterilised solution of alypin may be used. In dental practice, 1 to 2 c.c. of a 1 per cent. to 2 per cent. solution, with the addition of 2 drops of an adrenine (1 in 1,000) solution to each c.c., is said to produce insensitiveness.

Although recommended by some surgeons, alypin does not appear to be a particularly safe drug for spinal analgesia.

TROPACOCAINE.

Tropacocaine, $C_{15}H_{19}NO_2$, is an alkaloid which occurs in small quantities in Java coca leaves. It can also be prepared synthetically. The hydrochloride of the alkaloid is a crystalline substance freely soluble in water. Aqueous solutions of the hydrochloride keep well, and they may be boiled without fear of decomposition. It has been used largely in spinal analgesia, the usual dose being 0.08 gramme (1.25 grains). It is said to cause few after effects; but some observers have reported sequelæ similar to those which have followed the use of stovaine and novocain. It is difficult to arrive at conclusions upon this point, as it is too often the custom to condone the occurrence of undesirable after effects, and to ascribe them to errors of technique. Tropacocaine has been used in dental surgery.

ADRENINE.

Solution of adrenaline (1 in 1,000). Liquor adreninæ hydrochloricus, Brit. Phl. Codex, is made by dissolving adrenaline in normal saline solution, acidified with very dilute HCl. It contains 0.5 per cent. of CHCl_3 as a preservative.

Adrenaline in the solid form will keep indefinitely; in solution it decomposes very slowly and then turns *brown*. The solution turns *pink* with a very slight trace of NH_3 , which it is liable to absorb from the atmosphere.

Adrenaline in **very** dilute solution can be boiled for a short time without fear of decomposition.

A large number of preparations derived from the adrenals are obtainable, and are supplied under various names.

One part in 200,000 of adrenaline produces marked ischæmia, and no more than 1 mg. (about 15 drops of 1 in 1,000 solution) should be used in the course of an infiltration. Usually less is needed, and when the larger quantity is employed, great dilution becomes necessary, or toxic symptoms, palpitation of the heart, precordial oppression, and respiratory distress rapidly supervene.

Its **physiological action** is to contract the walls of the blood-vessels and capillaries. It is a greyish white powder, slightly soluble in water, readily so in weak acids. It has no intrinsic analgesic effect, but when added to true analgesics it increases their effect. Even minute doses such as those employed by dentists are said to cause unpleasant effects, *e.g.* giddiness, fainting, and collapse. The synthetic produce is stated to be less toxic than that prepared from the gland; it is, moreover, of definite strength, and so gives more precise reactions.

Synthetic suprarenine or dioxyphenylethanol-methylamine, $\text{C}_9 \text{H}_{13} \text{NO}_3$, is synthetically prepared and is therapeutically identical with the active principle prepared from the fresh glands. It keeps well and possesses constancy of action.

QUININE AND UREA HYDROCHLORIDE.

The compound is $\text{C}_{20} \text{H}_{24} \text{N}_2 \text{O}_2 \cdot 2 \cdot \text{HCl} \cdot \text{CO} (\text{NH}_2)_2 \cdot 5 \text{H}_2\text{O}$. It is made by adding urea to a solution of quinine in HCl,

filtering and crystallising. The crystals are soluble in their own weight in water.

Solutions containing 0·25 to 1·0 per cent. of the salt are used to produce local analgesia.

Analgesia is said to be produced in from ten to thirty minutes, and may last for four or five days. The solution is infiltrated subcutaneously over the area to be rendered analgesic. Sloughing may follow its use.

The compound is non-toxic, and its solutions can be sterilised by boiling.

Dr. Crile and other American surgeons employ this preparation to prevent reactionary pain coming on during the first few days consecutive to an operation. It possesses the objectional property of producing a hard œdematous condition in the tissues infiltrated with it which persists for a considerable time after the injection, even for days or weeks.

METHODS OF EMPLOYMENT OF COCAINE.

Cocaine is used in the following ways :

1. Instillation into the eye.
2. Painting over mucous surfaces.
3. Subcutaneous injections.
4. Infiltration (Schleich and Reclus' methods).
5. Spinal analgesia.
6. Neural analgesia.

Whatever method be adopted, it should be remembered that a **dose** of 0·065 gm. will in a large number of persons produce unpleasant, if not dangerous symptoms ; half this is a safer dose, though even this may in many people give rise to trouble.

1. In **ophthalmic practice** a few drops of a 4 per cent. solution are instilled into the conjunctiva ; this is repeated two or three times at brief intervals, and then five to ten minutes are allowed to elapse before operating. If the manipulation takes long, it will be necessary to repeat the process from time to time. Another and useful method of administration suitable for eye work is the placing of an easily soluble cocaine tablet in the oculofacial fold of the conjunctiva.

2. For **cutaneous and mucous surfaces**.—As a paint, it is of little use over cutaneous surfaces as it is not absorbed. When employed for mucous surfaces, especially if there be any possibility that some of the solution may be swallowed, a dilution of 5 per cent. should be adopted. In laryngoscopic and rhinological examinations some recommend a 20 per cent. solution, painting the nasopharynx with it. When strong solutions are employed great care must be taken to mop away all excess. Cocaine appears to be especially dangerous in the urethra and should not be used in this situation.

Cocaine is also employed as a spray in an atomiser, a 4 per cent. solution being used.

In rhinological examinations, a dossil of wool soaked in a 5 per cent. solution is placed in the nares until sensation is lost.

3. **Hypodermic injection**.—Most marked effects, both local and constitutional, follow the use of cocaine when injected hypodermically. Employed in this way, its action is more rapid and more persistent than when applied as a paint or an ointment. Formerly a 10 per cent. solution was employed, and from 2 to 5 minims injected at the site of operation. As the effect may pass off before surgical interference has been completed, it was often necessary to inject a second or third dose, however. Great care must be taken to avoid the injection entering a vein, since it is probable that many of the deaths following the use of cocaine have resulted from this accident. From five to ten minutes must be allowed to elapse after injection before the knife is inserted. Injection of cocaine into the tissues is now seldom practised, except when the infiltration method is employed, and even then novocain or β -eucaine is employed in preference to cocaine; they are far less toxic and can be readily sterilised by heating.

Dose.—When highly diluted solutions of cocaine are employed for infiltration, 0·065 to 0·097 gm. in a 1 per cent. solution is stated by Reclus to be a safe limit, and double this dose when $\frac{1}{2}$ per cent. solution is employed. However, this is a large dose and is seldom now employed. The addition of adrenine is said to lessen the danger.

If cocaine is employed at all the dose must be kept small and the concentration low. In dental surgery a number of fatal cases have been reported due to the incautious injection of cocaine into the gums by unqualified persons who appeared entirely ignorant of the dangerous character of the drug they were injecting.

If used for infiltration it is combined with adrenine, which lessens its toxicity and does not decrease its analgesic properties.

INFILTRATION METHODS.

Schleich * of Berlin, Reclus † of Paris, and Oberst of Halle have practised methods of local analgesia by the endermic and hypodermic injections of greatly diluted solutions of various analgesic substances. Drs. Braun and Heinz have systematised and simplified Schleich's procedure, and in the following account of the infiltration method their directions are mainly followed.

Schleich's solutions are three in number :

	No. 1.	No. 2.	No. 3.
Cocaine Hydrochlor. . .	0·2	0·1	0·01
Morphin. Hydrochl. . .	0·025	0·025	0·005
Sodium Chlorid. . .	0·2	0·2	0·2
Aq. destill. sterilisat. ad. .	100·0	100·0	100·0

These solutions are employed according as a deep, medium, or evanescent analgesia is desired. Before the use of novocain with adrenine became popular Braun adopted the following non-isotonic solution composed of β -eucaine one part in a thousand of saline solution (sodium chloride eight parts) by weight. The β -eucaine is not decomposed by boiling, and so can be completely sterilised.

* "Schmerzlose Operationen," Berlin, 1899. In this exhaustive work all Schleich's earlier work is focussed.

† *Rev. de Chirurgie*, p. 158, Paris, 1899. See also "La Cocaine en Chirurgie," Paris 1895.

Struthers * gives the following solutions as satisfactory when cocaine or β -eucaine is used for subdermic injection :

I.	Cocaine Hydrochlor.	1 grain.
	Sol. of Adrenalin Chloride † (1-1,000)	12 drops.
	Sol. of Sod. Chloride (75 per cent.) .	2 ounces.
II.	β -Eucaine Lactate	1 grain.
	Sol. of Adrenalin Chloride † (1-1,000)	5 drops.
	Sol. of Sod. Chloride (75 per cent.) .	10 drachms.
III.	Cocaine Hydrochlor.	1 grain.
	β -Eucaine Lactate	1 grain.
	Sol. of Adrenalin Chloride † (1-1,000)	12 drops.
	Sol. of Sod. Chloride (75 per cent.) .	30 ounces.

But as is pointed out above, the use of such solutions has been practically given up in favour of novocain, although Reclus still prefers stovaine.

Technique of Schleich's endermic method.—The syringe is constructed to hold 10 c.c. (see fig. 80). The piston must be absolutely true, and all the junctions must fit accurately, otherwise the resistance offered by the tissues injected causes the solution to leak back above the asbestos piston. Such dense tissues as those of the sole of the foot, the scalp and periosteum of bones are extremely difficult to pierce and infiltrate, hence some persons pierce the skin with a tenotome before using the needle.

Braun's syringes are made so that they can be readily taken to pieces, boiled, and put together again. The solutions and syringe having been carefully sterilised and the skin thoroughly cleansed, the needle is inserted *endermically* and some solution injected. The needle is held almost parallel to the surface and a little of the solution injected, then, pushing the needle farther in, more solution is injected until the needle is completely buried in the skin. Needles of various sizes and angled hubs are needed. The first puncture should be made with a fine sharp needle as this gives

* "Local Anæsthesia in General Surgery," 1906. These solutions are, however, not isotonic.

† Adrenaline is merely a proprietary name for a material which is identical with adrenine. The use of the non-metric system should be noted. Mr. Struthers employs this notation.

least pain. The wheal resulting is again injected at its periphery, and this is injected in like manner until a linear zone of skin is rendered œdematous by the fluid introduced. Subsequent injections are made hypodermically, each one being made into the wheal and deeply into the subdermic structures, and when the deeper structures are to be operated upon these are also injected. It is advisable to wait for some twenty minutes, or longer, between the time of injection and the performance of the operation. When the structures are cut, much of the œdema fluid flows away, but the tissues remain analgesic for about twenty minutes. Repeated injections are made as the operation is in progress. Large quantities of the solution may be employed. It is usual to scheme the line of injections in such a way that all skin areas which are to be cut are made analgesic. The nerves supplying them, and the deeper structures also, are rendered incapable of transmitting painful impressions by injections made into the tissues surrounding them.



FIG. 80.—Syringe for use in local analgesia.

TISSUE INFILTRATION: BRAUN'S METHOD.

The solution, syringe, and needles are sterilised in plain water or saline, since soda destroys the analgesic effect: and the skin is cleansed. A 0·5 per cent. novocain and adrenine

solution is employed.* A fine hollow needle is fixed to the syringe (fig. 80), and introduced into the deep tissues, care being taken to avoid the proximity of blood-vessels. As the needle is slowly withdrawn the solution is injected so that the subcutaneous tissues are the last to become permeated. If the whole area cannot be reached by deviating the direction of the needle fresh punctures are made in the required direction, but always within the area already rendered analgesic. It will be found that for practically all areas a scheme of intersecting lines can be made which will intercept the nerves running from the area to the centripetal nerve trunks. It may be necessary or advisable to inject deeply beneath the growth or area to be operated upon, but this is not always required nor is it possible if large blood-vessels traverse the region to be infiltrated. The diffusion of the solution, although not great, will assist in isolating deeply the operation site. It is wise to infiltrate wide of the intended line of incisions, since it is not possible to anticipate all the eventualities of an operation until it has been commenced. The solution used should be freshly prepared and should be isotonic with the tissue fluids. Hence the solutions of novocain or other analgesic are made isotonic by the addition of sodium chloride. Both in Reclus and Braun's methods the endermic system of Schleich is replaced by subdermic injection, and the area infiltrated is controlled by the character of the operation to be performed. It is impossible to do more than indicate the rationale in a few of the commoner surgical procedures. The anatomy of the part and especially the distribution of the nerves supplying the area to be infiltrated control the precise lines of injection, since, besides infiltrating the tissues of the area involved, it is essential to inject the points of exit of the sensory nerves innervating the site of operation. A few drachms of solution usually analgesise an incision of three or four inches and produce a swelling over the injected area, which, however, gradually subsides.

* The solutions have been mentioned above (pp. 413, 416). Braun points out that when large quantities are to be infiltrated a dilute solution is advisable. The quantity of adrenine introduced is important, as an excess leads to serious damage to the tissues infiltrated. One milligramme may be added to 200 c.c. of a 0.5 per cent. novocain solution, to 100 c.c. of a 1 per cent. solution, to 50 c.c. of a 2 per cent. solution, and to 25 c.c. of a 4 per cent. solution.

Although fat, muscles, and fasciæ can be injected through the skin, it is always better, when working in the line of important vessels or highly vascular structures, to inject the deeper layers as they are exposed in the course of the dissection. Merely bathing tissues has no effect; the fluid must enter into their meshes to anæsthetise them. The time taken to produce an analgesic state varies with the tissue and the strength of the solution employed; it may be fixed at from ten minutes to half an hour, and it is easy to test the sensation. However, such testing should be undertaken out of sight of the patient and the result judged rather by watching his eye than by interrogating him as to whether he can feel anything. Few answers so obtained are of any value, since tactile sense often persists for some time after analgesia has been produced.

CHOICE OF OPERATIONS.

Although Professor Braun* indicates the possibility of performing operations upon practically every region of the body, it is less usual in this country to adventure with the use of analgesia upon those operations which involve difficult and deep injections into the foramina of the skull, or call for deep dissections.

Operations upon digits and toes, circumcision, Thiersch's skin grafting, simple hernias, hydroceles, thyroidectomies, removal of circumscribed growths, sebaceous or dermoid cysts, fatty or fibrous tumours, warts, moles, etc., are commonly considered appropriate cases for local analgesia. When regional methods are adopted the range of operation is extended, as resection of ribs for empyema, removal of gangrenous extremities, resection of varicose veins, excision of ganglia, and so on, can be readily performed by the aid of this method. The danger of injecting in the region of septic areas and the inadvisability of trusting to local methods when it is impossible to foretell the limits of the operation must be kept in mind in making the choice between local and general

* For full particulars of Professor Braun's elaborate procedures in the use of local analgesia, the reader is referred to his work "*Lakalanæsthesie*," Dritte Auflage, J. A. Marth, Leipzig, 1913.

anæsthesia. Nor must it be forgotten that nervous, neurasthenic and highly strung patients suffer from nerve shock when they are conscious, so that such persons and children are not as a rule suitable for local methods. Some authorities, recognising this, advocate the employment of a mixed method. They either use the preliminary injections of scopolamorphine and atropine, or even associate a light narcosis such as that of nitrous oxide and oxygen with these drugs and local infiltration (see pp. 353 and 363).

REGIONAL (CONDUCTION) ANALGESIA.

As the modern method of local anæsthesia is usually one involving local infiltration with injection into the perineural tissue it is obviously impossible within the limits of this manual to give in full detail the requisite anatomical guides which must control the more complex procedures such as injecting the brachial plexus, the trunk nerves of the limbs, and the nerve trunks in the head and neck. It will, however, be useful to describe a few operations to serve as types. Some of these are done by the "local," and some by the regional method. It may be pointed out that when a septic focus exists it is safe to use a regional method as the injections are made at a distance from the infected area. Although it is seldom advisable to perform extensive abdominal operations under regional analgesia, yet in such rare cases as those when the method is forced upon the surgeon, it is useful to remember that the abdominal parietes are readily infiltrated, and, that cutting the viscera does not give rise to pain unless traction is made upon them. Lennander,* whose careful work may be consulted, has shown this while he has demonstrated that the parietal peritoneum is, however, very sensitive.

Operations on digits (*Regional*).—After sterilisation of the syringe needles and the novocain-adrenine† solution, the skin

* *Deutsche Zeitschrift f. Chir.*, band lxxiii.

† A 1 per cent. or 2 per cent. novocain with sodium chloride answers well; 5 drops of 1 in 10,000 solution of adrenine should be added to each 20 c.cm. at the time of use—a 1 per cent. solution of novocain is used for infiltration, and a 2 per cent. solution for conduction analgesia.

is pinched up on the dorsal aspect of the finger, and a fine needle stabbed in close to the bone. The solution is slowly injected while the needle is pushed in until its point is near the palmar aspect. During withdrawal more solution is injected, about 20 to 30 drops in all, according as the finger or toe is slender or thick. A similar injection is then made on the other side of the digit. In ten minutes, if no swelling appears about the root of the digit, the needle may be re-introduced through the former puncture, and more solution injected, but across the base of the finger. If the line of incision is other than that indicated the injection must be varied to suit this requirement. When the hand or foot is to be operated upon it is best to infiltrate over the nerve trunks supplying the regions and inject in the line of the nerves themselves. Some surgeons use a Martin's bandage or rubber cord to produce first venous engorgement, and ultimately hæmostasis, but this is seldom necessary if adrenine is added to the solution. It is also stated that when the cord or bandage is used at the same time that adrenine action exists, there is danger of permanent injury to tissues and even of gangrene.

Small subcutaneous growths, e.g. sebaceous cysts, fatty tumours (*Infiltration*).—The growth is carefully surrounded by a ring of subcutaneous injections. The infiltration can usually be done from four to five punctures, each successive puncture being made within the line already rendered analgesic by the preceding injection. Then the line of incision is infiltrated, and the solution, if possible, is also introduced below the growth and between it and the skin.

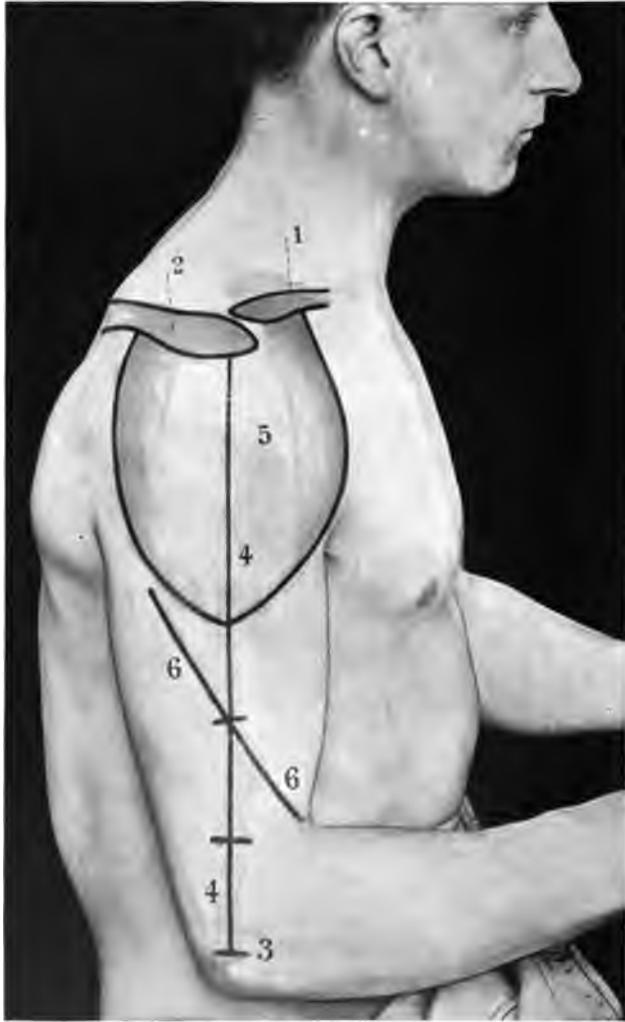
Circumcision.—The prepuce is stretched taut, and the needle inserted anteriorly on the dorsal aspect, being gradually pushed to behind the corona. The infiltration is carried on as the needle is advanced. The whole of the prepuce is then slowly infiltrated from the original injection area, and will rapidly grow œdematous. It is wise to wait a good time before incising, as the fluid escapes as soon as the loose tissues are opened. This procedure should not be pursued if inflammation or purulent infection exists, nor is it suitable for children. Sometimes a regional method is attempted.

Radical cure of hernia (*Inguinal*).—The internal abdominal ring is sought for and the needle introduced one inch or one and a half inches outside this. The line of incision will extend inward to the root of the penis and must be widely infiltrated, the fluid being forced just below the skin. Half to an ounce of solution will be required. The next injection is made in the region of the cord and through the aponeurosis of the external oblique muscle. It is best to hold the syringe as nearly parallel to the skin as possible and to infiltrate the internal ring as thoroughly as can be, that is, the region about the neck of the sac. The external ring must then be carefully infiltrated. It is occasionally necessary to re-inject some of the tissues as the dissection proceeds, so a syringe ready filled should be at hand.

Umbilical hernia.—Here the injections are made round the tumour, great care being taken that when the peritoneum is reached no puncture is made into any gut which may lie in the sac. It is impossible to infiltrate the neck of the sac before the operation is commenced unless the finger can be introduced into the ring, so that a second infiltration should always be made beneath the aponeurosis when that structure has been laid bare. This is especially needful in the case of a strangulated umbilical hernia.

Thyroidectomy.—It is only possible to render the skin and subcutaneous tissues analgesic as the relations of the structures underlying the goitre render deep injections dangerous. The operation is rendered less painful, but not entirely free from distress, especially when the goitrous growth is being dislocated, so the patient must be prepared for this, or fear of worse pain in store may cause syncope. It should, however, be remembered that cases vary, and individuals differ in their perception of pain so that while some will say they suffer severely others deny any real pain. A wide ring of injection is made round the growth and across the line of incision, an effort being made to infiltrate the muscles. The position of the adjacent vessels and other structures must be accurately in the mind of the anæsthetist during his injections. Dr. Crile prefers to use nitrous oxide and oxygen following the scopolamorphine and atropine injection in association with local analgesia in cases of thyroidectomy.

PLATE VI.



1. The clavicle.
2. The acromion process.
3. The external condyle of the humerus.
- 4, 4. Hamilton's line.
5. The deltoid muscle.
- 6, 6. The musculo-spiral nerve.

OPERATIONS ON THE RIBS.

The region to be operated upon is infiltrated along the line of the proposed incision and wide of it. Subsequently an attempt is made by the use of right-angled needle-hubs to infiltrate the periosteum covering the ribs to be resected, by introducing the needle over the rib, and there infiltrating the deep tissues. The better plan, however, is to attempt a regional anæsthesia. If this is done the ribs affected are marked, and a needle is introduced at the upper surface of the highest, if possible to the outer side of the erector spinæ muscle of the affected side. The needle will be felt to impinge upon the rib, and it is then withdrawn slightly and directed downwards until it slips into the subcostal groove along which the nerve runs, and 3-5 c.c. injected. This area being thoroughly analgesed, a similar procedure is adopted for the lower ribs. It is best to analgesise the intercostal nerve trunks of a couple of spaces wide of the region of the contemplated resection. Ultimately the skin and subcutaneous tissues in the line of the skin incision and an inch or so wide of it are infiltrated. Dr. Rood * suggests making the injection near the angle of the ribs in the following way. The patient lies on his back with his arm raised. The needle is introduced below the level of the rib and turned upwards until it just touches the lower edge of the rib; it is then slightly withdrawn and pushed in until it just misses the lower edge, when it will enter the subcostal groove and can be pushed in for a quarter of an inch and the solution injected.

LINES OF NERVES IN REGIONAL ANALGESIA.

The success of regional analgesia resolves itself into an exact knowledge of the position and distribution of the nerves of various areas likely to be involved in an operation, as well as the surface guides to the positions at which the nerve trunks can be found. The procedure of first infiltrating a region and then dissecting down upon a nerve trunk which is subsequently injected, is too complicated a procedure to be lightly

* *Brit. Med. Jour.*, Dec. 21, 1912.

undertaken. There are, however, certain nerves which can be located fairly easily and injected from the surface without dissection, and some of them may be indicated.

In the case of the upper limb, the **musculo-spiral nerve** (Plates VI. and VII.B) perforates the external inter-muscular septum running from behind forwards at a point joining the upper third with the middle third of a line between the insertion of the deltoid and the external condyle of the humerus (Rawling).

The **median nerve** (Plate VII.A) runs in front of the wrist to the ulnar side of the flexor carpi radialis beneath the tendon of the palmaris longus.

The **ulnar nerve** (Plate VII.A) is accessible in the forearm, as it lies in the hollow between the internal condyle and the olecranon process. At the wrist it is placed to the outer side of the tendon of the flexor carpi ulnaris. The needle is entered between the bone and the nerve, close to the former.

The **radial nerve** (Plate VII.A and B) is less easily found. It lies in the middle third of the forearm to the outer side of the radial artery, then passes under the tendon of the supinator longus to the outer side of the radius.

The **internal cutaneous nerve** can be blocked at the elbow at a point three-quarters of an inch internal to the biceps tendon.

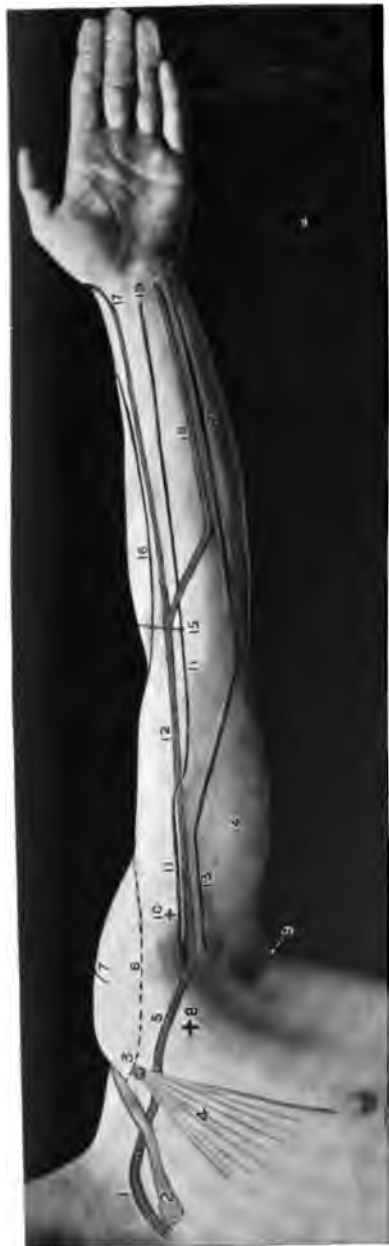
The **musculo-cutaneous nerve** lies to the outer side of the biceps tendon. In both these cases the injection must be made to the deep fascia.

THE LOWER LIMB.

The **anterior crural nerve** (Plate VIII.B) passes under Poupart's ligament midway between the anterior superior iliac spine and the spine of the pubes, and lies half an inch outside the common femoral artery.

The **great sciatic nerve** (Plate VIII.A) lies in a line taken midway between the ischial tuberosity and the great trochanter, passing vertically downwards to the popliteal space. It divides at the junction of the lower and middle thirds of this line, and can be found as it emerges from the hamstring

PLATE VII.



A.

7. Circumflex ulnar nerve. 11. Median nerve in the arm. 13. Ulnar nerve in the arm. 16. Radial nerve. 19. Median nerve in the forearm.
20. Ulnar nerve in the forearm.



B.

1. The acromion spine. 2. The acromion process. 3. The circumflex nerve and arteries. 4. The insertion of the deltoid. 5. The external condyle of the humerus. 6. The musculo-spiral nerve. 7. The posterior fold of the axilla. 8. The radius. 9. The posterior interosseous nerve. 10. The radial nerve.
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PLATE VIII.



A.

- 12. Great sciatic nerve.
- 13. Internal popliteal nerve.
- 14. External popliteal nerve.
- 21. Posterior tibial artery and nerve.



B.

- 4. Anterior crural nerve.
- 20. Anterior tibial nerve.
- 21. Musculo cutaneous nerve.

muscles. However, it is more convenient to block the smaller branches than the main nerve.

The **external popliteal** (peroneal) nerve (Plate VIII.A) follows the tendon of the biceps, passing round the fibula an inch below the head to the anterior and external aspect of the leg, where it divides. It can usually be felt as it winds round the bone. The needle has to be pushed down to the bone.

The **posterior and anterior tibial nerves** accompany the arteries of the same name (Plate VIII.A and B).

ANALGESIA IN DENTAL SURGERY.

For the adjustment of clamps and separators, the introduction of wedges, the application of ligatures for the rubber, for excavating, filling, trimming, or polishing deep cervical edges of cavities, the removal of tartar in pyorrhœa alveolaris, the modelling of sensitive and irritable mucous membranes, cocaine as a paint of a 10 per cent. strength is used, or a spray of 2 to 4 per cent. according to the degree of sensibility manifested by the parts, or an equivalent of novocain. Cocaine or novocain is used before lancing and excising gum-tissue, and for the relief of pain after extraction, though it is usually inadequate to accomplish the latter. For anæsthetising pulps before extirpation cocaine or novocain is also used.

Cocaine is not satisfactory for tooth extractions; small doses are inadequate, and larger ones too frequently give rise to constitutional derangement which is often alarming. As a rule, 0.065 gm. is needed to anæsthetise sufficiently to permit of extraction, and ten minutes must be allowed to elapse before applying the forceps. The method of making the punctures and their position are given below in describing the use of novocain, a drug which has replaced cocaine in dental practice.

NOVOCAIN AND ADRENINE IN DENTAL SURGERY.

What has been said above concerning the superiority of novocain over cocaine in general surgery applies equally to dental operations. Although the routine employment of analgesics in this connexion has many drawbacks and

should be carefully avoided when septic conditions are present, yet at times the method is of great value. It must be admitted that complete loss of pain cannot be invariably secured while sloughing and damage of the tissues may follow injection ; but these incidents, undesirable as they are, frequently arise through failure of technique.

Two methods are open for adoption : (1) local injection, which is the one most usually employed in this country ; and (2) regional injection, wherein one of the trunks of the nerves supplying the teeth is analgesed at the point where the nerve enters the bony canals of the maxillæ or mandible.

Dr. Pare* impresses the importance of complete cleansing of the gums. To this end he recommends a preliminary scaling of the teeth, washing the mouth with warm carbolic solution, and careful sterilisation of the hands of the operator, of the syringe, and of the solutions. An additional safeguard is painting the area of operation with solution of iodine or spirit. One of the best forms of syringe is the all-metal one of the "Record" type, with an accurately fitting asbestos piston and fine needles, which should be kept in alcohol. Various hubs are necessary to carry these needles.

Ampoules containing 1 c.c. of 2 per cent. novocain solution, *i.e.* novocain 0.021 gm., adrenine 0.000081 gm., and sodium chloride, can be procured, as well as tablets. These last contain 0.021 gm. novocain and 0.000054 gm. of adrenine borate. One tablet dissolved in 1 c.c. (17 minims) of sterilised distilled water, or, what is better, in normal saline solution, gives a 2 per cent. solution. One to three tablets may be used for a dental operation, but three are seldom required. The preliminaries must be carefully carried out, and ample time allowed for so doing, since haste generally leads to failure. The gum can be rendered insensitive by surrounding it with a dossil of cotton wool soaked in 10 per cent. novocain solution. This is left applied for five minutes. When the gum is analgesic and somewhat blanched the injections can be made. The needle is inserted into the gum about one-eighth of an inch from its margin, the needle being held

* See useful papers by this author : *Trans. Odontol. Soc. of Great Britain*, March 1907 ; *Brit. Med. Jour.*, May 18, 1907 ; *Trans. of the Liverpool and District Odontol. Soc.*, Nov. 1907.

at a right angle to the long axis of the tooth. The first puncture should be made on the lingual aspect, and a few drops of the solution forced out, before the needle, turned to an acute angle to the long axis of the tooth, is pushed down to the periosteum. This point attained, the remainder of the solution is injected. Some time must be allowed to elapse—half a minute between each injection. The buccal injections are made similarly. By the use of angular attachments, the posterior teeth can be successfully approached. One to three punctures are required, according to the tooth, while in the case of solitary standing teeth, a ring of several punctures round the tooth may be necessary.

It is unsafe to inject any tissues which are acutely inflamed or septic, and unless a conduction analgesia is adopted multiple tooth extraction under local analgesia is undesirable.

When the injections have been made there will be some blanching due to the submucous injections, and the appearance of this is usually a sign that analgesia is present, provided of course that the deeper injections have effectually paralysed the nerves of the underlying structures. Analgesia usually develops in five or ten minutes. There is always a liability of escape of the solution through fistulous openings and through the sockets of adjoining teeth, or into soft spongy gum. In these cases the deeper structures will retain their sensibility, and the extraction will be painful. In the case of teeth which are awkwardly placed such as upper wisdom teeth, the best plan is to scheme the injections so that they are made in the line of the nerves supplying the teeth. The tissues of the gums and periosteum are very dense, and unless care is taken the slender needles will break. They are especially liable to do this if they are not kept from bending, or are hurriedly pushed home. It will be found that when in one place a needle will hardly enter any distance; if it is withdrawn a centimetre or so without being entirely free from the gum its direction of entry can be altered and a more easy way found. As a rule the final injection should find its way between the roots of the teeth rather than alongside of a root. Twenty minims of a 2 per cent. solution are usually sufficient to analgesia a single tooth.

CONDUCTION ANALGESIA.

Although with accurate anatomical knowledge and extended practice it is possible to inject even the gasserian ganglion and more easily the inferior dental nerve and nerves supplying the teeth in the maxillæ, yet such procedures are by no means easy or devoid of danger. The more extensive operations such as paresing the ganglia will not be described here. The reader will find a careful description of them in Professor Braun's book to which reference has already been made.

The **inferior dental nerve** can be located behind the protecting process of bone, the lingula, as the nerve enters the foramen. Between the two ridges of bone on the anterior surface of the ascending ramus is a hollow groove and the inner oblique line is the guide to the position of the nerve. The syringe should lie behind the canine of the opposite side and the needle be introduced along the internal surface. The foramen is higher in the adult jaw than in the child's, and the needle's course must be altered accordingly. The point of introduction should be 1 c.m. above the level of the masticating surface of the molar teeth. No attempt should be made to effect an intra-neural injection lest the veins are damaged. If the perineural structures are infiltrated the nerve will become paresed. In the case of the incisors this injection will not be sufficient as they receive an additional nerve supply, and hence either this must be dealt with by injections into the mental foramen, or a submucous injection made about the teeth in question; unless care is taken, deglutition may be interfered with.

Posterior dental nerves.—Conduction analgesia of the nerve supply to the upper teeth is less simple, for although the nerves can be located as they enter the hard palate, the anterior branches cannot be injected without causing considerable pain. The anterior superior dental nerves can be found in the infra-orbital foramen, which is situated $\frac{1}{2}$ c.m. below the lower edge of the orbit and vertically above the first premolar tooth. Not more than 1 c.c. should be injected.

DISADVANTAGES AND DANGERS.

Whether after-pain consecutive to analgesia is more severe is doubtful. Some state that it is absent, but many assert that it is often severe and prolonged. It certainly varies greatly in individuals, so that it is unwise to assure the patient that none will occur. Tissues of low vitality often react badly towards local injections, and these, with tissues which are inflamed or septic, are prone to slough and leave bared bone to exfoliate. No doubt rigid asepsis minimises the liability of such happenings, and many observers of great experience deny that they have met with these accidents. Nervous persons and children feel the strain of the somewhat prolonged programme requisite for local analgesia. Relatively large injections even of novocain may cause circulatory depression and faintness, partly due no doubt to the patient's apprehension, although he will blame the method for these discomforts. Injections through an area of septic tissue are liable to inoculate the healthy tissues and cause abscess. Some operators have found that the use of adrenal products produces localised necrobiosis, and it is well to remember that the synthetic suprarenin is less liable to lead to this unfortunate issue, especially if the dose is kept low. Generally it should be recognised that, provided the dilution of the analgesic is high, there is less danger of evil effects accruing. A case has been reported of erotic hallucination following the injection of novocain which only developed after the patient had left the dentist's house. This is a warning that even local analgesia should not be undertaken unless in the presence of a witness.

Safety of analgesics.—The behaviour of these drugs towards the tissues has been studied by Dr. Le Brocq.*

Toxicity: Taking cocaine as 1, his results are: alypin, 1·25; nirvanine, 0·714; stovaine, 0·625; tropacocaine, 0·50; novocain, 0·490; β -eucaine lactate, 0·414.

Irritant action on tissues: Novocain least; cocaine slight; all the remaining drugs caused hyperæmia, dilatation of the vessels, and ultimately some sloughing.

* *Brit. Med. Jour.* 1909, vol. i. p. 783.

The subject of producing analgesia for the various conservative operations of dentistry does not fall within the limits of this book. The whole subject is carefully described in Professor Guido Fischer's elaborate treatise on *Local Anæsthesia in Dentistry*, and the reader is referred to this work for detailed information.

THE METHOD OF SPINAL ANALGESIA.*

Spinal analgesia consists in the injection *into* the subdural space of some agent which will act upon the nerve roots as they pass into or from the spinal cord. Their conduction is blocked and so the area innervated by the nerves associated with the segment or segments affected becomes wholly insensitive to trauma. Whether the conveyance of every stimulus is blocked appears to be undecided, but the consensus of opinion seems to be that shock is more or less abrogated by this procedure. The drugs most commonly employed in this country are stovaine, tropacocaine, and novocain (see pp. 411 *et seq.*). The technique varies in the practice of many surgeons, but that of Mr. A. E. Barker, with which most workers in this country agree, will be followed in the main in the appended description.†

The figures show the syringe and needles which are requisite, and the solutions recommended are given on p. 412.

The dose of the stovaine-glucose solution is 3 to 6 centigrammes, an average dose for the adult being 5 centigrammes. The postures assumed by the patient are accurately depicted by figs. 81 and 82, which are from photographs by Dr. E. Worrall, and are reproduced by Mr. Barker's permission from his paper dealing with the subject. Analgesia usually develops in from five to fifteen minutes. The symptoms are formication in the feet, disappearance of the cremasteric and patella reflexes, followed by skin analgesia in the perinæum and lower limbs and gradually higher and higher up the body to the xyphisternal notch. The height reached depends upon

* Although Leonard Corning suggested intra-dural injection of drugs, yet to Bier is due the credit of initiating the method of Spinal Analgesia.

† See Mr. Barker's original papers, *Brit. Med. Jour.* March 23, 1907; Feb. 1, 1908, and Aug. 22, 1908, with March 16, 1909.

the dose and upon the depression of the dorsal curve. Analgesia persists for from twenty minutes to as long as two hours in exceptional cases ; the dose is an important factor in determining the duration. Although some continental surgeons employ adrenal derivatives, while others add strychnine to the injection, in this country the general opinion of those who have enjoyed the widest experience is opposed to any such additions.* The mechanism by which the fluid injected traverses the cerebro-spinal fluid is of great importance, as it is essential that the area of influence of the analgesic shall be confined within safe limits. If this is not done, there is danger of its effects trenching upon the medulla and interfering with the nerve controls over respiration and circulation. Opinions differ as to this mechanism, and the position of the patient is decided by the view adopted. However, the adoption of the Trendelenburg position, although supported by the authority of Tuffier and others, and the selection of any region of puncture above the first lumbar spine are certainly open to grave criticism and had better be avoided, even when light solutions are employed. Indeed the evidence of such extreme practices as the high dorsal and cervical puncture fails to carry conviction as regards their safety even when strychnine is used concurrently with the analgesic. Careful dissections made of the cord and its coverings indicate that there is least danger of doing damage to the cord or the *corda equina* when the region of the lumbar spine is selected. In children the cord extends lower than in adults. The best point of puncture is usually between the spines of the third and fourth lumbar vertebræ ; some surgeons advocate the interspace between the fourth and fifth, but this position is often difficult to negotiate owing to the irregularity of the spinous processes.

Barker emphasises the importance of the injected fluid possessing certain properties. It must be aseptic ; it must produce transient and not permanent effects ; its use should enable the effects to be strictly localised to such nerve roots of the cord as the operator desires to influence, thus ensuring the safety of the medullary centres.

Stovaine may be kept for fifteen minutes at 115° C.

* The addition of adrenal derivatives is probably dangerous on account of their causing paralysis which persists even if they do not permanently injure the cord.

without damage. Barker also insists upon the injected fluid having an osmotic tension equal to that of the blood serum. Such a solution containing stovaine is found in Barker's stovaine-glucose solution, and although like all stovaine solutions, this is hæmolytic, yet the amount of the destruction of tissue cells must be very slight when 5 centigrammes are injected. The question of the advisability of using a heavy or a light solution is an important one, and depends upon whether we accept the view that the passage of the injected fluid through the liquor spinalis is due to diffusion, oscillation, and movement of the liquor spinalis, or is controlled by gravity. Barker, in the paper cited above, describes some careful experiments *in vitro* which seem to warrant his statement that gravity can be made to be the main factor in the process. At all events, when a heavy more or less viscid iso-osmotic fluid is employed, the surgeon retains control of the amount of excursion of the injected fluid. With the body on the side or on the back, and the head raised on a pillow, the highest point in the curve of the spinal canal is the foramen magnum. The lowest is in the region of the fifth and sixth dorsal spines. The curve rises above to the third cervical vertebra, which is the highest point of the vertebral column proper, and below to the junction of the third and fourth lumbar vertebræ, the point of election for puncture. From this spot downwards it falls to the level of the third sacral vertebra, where the dura ends. With these facts in mind, it will be recognised that by raising the trunk, as in the crouching posture shown in fig. 81, the injected fluid tends at once to gravitate downwards into the sacral sac so that only the lower parts of the pelvis and the lower limbs become analgesic. Conversely, if the patient is injected when lying on his side (fig. 82), or when prone, and is then turned into the supine position, the region of the mid-dorsal vertebræ is affected, and the analgesia ascends to the xyphisternal notch. When the buttocks are raised not more than an inch by a padded board under the sacrum, the fluid will ascend higher provided time is allowed for the action of gravity. The safety of the medulla depends, then, upon the head being kept high and bent somewhat forwards in order to emphasise the cervical curve.

Technique.—The syringe, needle, cannula, and stylet should be used only for spinal work ; they should be carefully washed in sterilised water immediately after use, especially if a glucose mixture has been employed, and carefully sterilised by boiling. It is essential that no soda is present during the process, or the analgesic power of the drug will be destroyed. It is best to keep a small steriliser for this purpose, and for this alone.

The solution in ampoules holding about 2 c.c. is already sterilised, but if a solution of stovaine and glucose has been freshly prepared, it must be subjected to a temperature of 212° F. for fifteen minutes.

The skin of the patient's back must be carefully cleansed with soap and water, subsequently wiped over with spirit. If painted with iodine water must not have been previously used. At the moment of puncture no antiseptic must be on the skin, as its introduction into the theca will cause irritation. The patient need not pass through the rigid stage of fasting prescribed before general anæsthesia, but as some sickness is not very uncommon after spinal puncture, it is as well to let him have his meal two or three hours before the operation, and restrict it to easily digested liquids. Some persons suggest giving alcohol just before the puncture, but this is usually quite unnecessary, and is obviously undesirable.

In the case of very nervous persons a preliminary hypodermic injection of scopolamine, morphine, and atropine is sometimes given. The procedure is usually best omitted, as it complicates the problem if respiration is hampered, and in any case the doses should be smaller than those usually exhibited. Again, it is a practice with many surgeons abroad to spray the skin with ethyl chloride before puncture, or to infiltrate it with novocain or β -eucaine lactate. Save in exceptional cases, however, it is best to avoid elaborating the procedure and fussing the patient, who, if he has never undergone the process, is naturally somewhat nervous.

The patient is now placed in position on the operating table. If the crouching posture has been selected (fig. 81), the patient sits upon the table with his buttocks towards the operator, his feet resting upon a chair, and his body bent forwards and downwards, his hands resting upon his knees.

The lumbar spines should be made prominent, and this will be effected by the forward arching of the body. If left to himself the patient will keep his back straight and incline his axial line at an acute angle to the table. He must be made to bow his back out to the requisite degree.

In the lateral position, which, although less easy for the operator, gives a higher and more prolonged analgesia, the



FIG. 81.—The patient sitting on the table with his buttocks on the edge, his body bent forwards to bring the spinal curve into prominence. From a photograph by Dr. Worrall.

lower shoulder is carried forwards, the head raised and flexed on the chest, and the thighs strongly flexed upon the abdomen. The whole trunk is made to incline backwards, so that the side which is uppermost is in a plane slightly posterior to the lower, that is, is a trifle nearer the operator, who sits upon a stool facing the patient's back. In this position the curves of the spinal column should be readily traced, and the lumbar spines prominent. In stout persons and in muscular men the

spines are not so easily made out, but by forcible flexion of the head and lower extremities they can usually be felt on deep pressure.

In the figure the pelvis is raised upon a block, but this degree of elevation is seldom needed unless the pelvis is very narrow or high range of analgesia is sought. The insertion of a one-inch board covered with mackintosh and a sterilised towel, usually suffices, but the degree of elevation must be judged of in each case by the inspection of the pelvis and

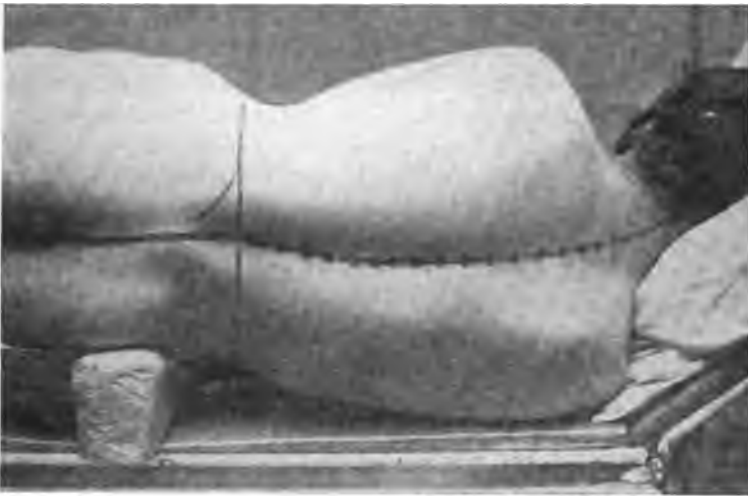


FIG. 82.—The patient lying on his side in the correct position for puncture, except that the upward bent thighs are not illustrated. From a photograph by Dr. Worrall.

consideration of the necessities of the operation. As a rule, it is best to restrict the method to operations upon the lower limbs, pelvis, and lower half of the abdomen. In women with a broad pelvis nothing is required under the hip.

The line connecting the highest point (*i.e.* in the erect posture) of the iliac crests will pass over the superior aspect of the spine of the fourth lumbar vertebra, so that the point of election for puncture will be immediately above this, between the spines of the third and fourth lumbar vertebræ. Although some authorities advise that the puncture should be made to the side of the line of the spine, the needle

taking the direction shown in Plate I. (frontispiece) with the view of avoiding the supraspinous ligament, yet the central puncture is certainly the best and less likely to go astray, or to wound the nerves and veins which lie on either side of the middle line.

The operator now takes the hollow needle with the stylet in his hand. The skin over the spines is kept taut by the first and second fingers of the left hand, and the needle made to pierce the skin with a sharp dig, its entry being controlled by a finger of the right hand. It is wise to warn the patient that he will feel a sharp prick, otherwise he will straighten his back and the course of the needle will be deflected and the line of the spines lost. The needle should be introduced between the spines inwards (forwards in this position) and slightly upwards, but kept rigidly in the middle line. As it passes through the supraspinous and interspinous ligaments a slight holding or clinging of the needle is felt. The needle having entered for about an inch, the stylet is withdrawn and the needle pushed on into the canal; as it passes through the dura, a sense of a thin membrane giving way is experienced. The liquor spinalis should now escape in drops or continuously. In any case the needle should be turned, and the patient told to cough. Should no fluid come, or merely a drop or so of blood, the canal has not been entered, or the needle eye is occluded. The needle should be slightly withdrawn and again pushed home. Failing success a fresh puncture must be made, either in the same space or in the one next above. It may in exceptional cases be necessary to make the patient sit up and puncture in the position shown in fig. 81. If, however, fluid freely escapes, about 10 c.c. are allowed to drop, and then the syringe and cannula are taken and the latter is passed through the hollow needle into the canal, and 1 c.c. of the stovaine-glucose solution slowly injected. This completed, the cannula and needle are withdrawn, and the puncture covered with a small piece of sterile strapping, and the patient after two or three minutes is quietly turned over on his back, his head being kept high. During the after proceedings there should be a screen between the patient's head and the site of the operation.

Various minor mishaps may occur during the injection.

There are plexuses on the posterior aspect of the body of the vertebræ and at the sides of the canal, so that if the needle is pushed too far in or is lateralised a vein may be wounded. If blunt the needle may push the dura in front of it, and so not enter the space, or may be occluded by the nerves, which lie laterally, or by blood-clot. Again, when the middle line is not kept to, the needle may strike the spines or laminae, and so fail to enter the canal. The sensation of touching bone is easily recognised. It may happen that the needle's eye only half enters the dura, and in this case, although the spinal

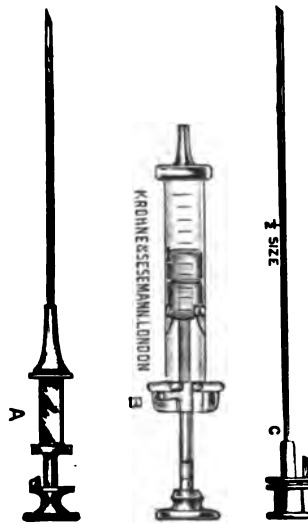


FIG. 83.—A. Hollow needle and stylet with catch which indicates the direction in which the edge of the needle is bevelled. B. Syringe. C. The cannula, also fitted with catch. (Mr. Barker's pattern.)

fluid will escape, yet the injection from the syringe will not enter the canal, but be dissipated in the tissues adjacent. It is essential, therefore, that spinal fluid escapes before the injection is made, and that the dural sac has been properly entered. The cannula devised by Barker renders this possible. It is so made that when it is driven home its end projects 1 m.m. beyond the extremity of the hollow needle, and so when it is pushed home the cannula must

be within the dural sac, and the fluid injected through must enter that space. To avoid rusting, Barker recommends that the cannula, needle, and stylet should be made of pure nickel, as is now almost always the case. It is important also that the needle and cannula should be cleansed as soon as they have been used, and thoroughly dried since the lumen is easily choked if put away damp.

The first signs of the action of the drug when injected in the sitting position are formication and analgesia in the perinæum and upward and downward, commonly as high as the xyphisternal notch. If the patient is kept upon his side formication in the feet is first noticed, and then the underlying side of the body may be analgesic, but the area supplied from the corresponding hemi-segment of the uppermost side may be only partially or not at all analgesic. It is best not to question the patient as to his sensation since tactile feeling commonly persists to some extent, and he will regard a touch as tantamount to painful sensation. When the screen is placed so that he cannot see, it is easy to test sense of pain by lightly pinching the skin from the seat of injection, upwards or downwards as occasion requires, and noticing whether he evinces any shrinking or expresses his discomfort. The power of moving the limbs is not always lost although usually impaired, and the patient will move a foot if required to do so. Within the first ten minutes subsequent to the injection, pallor and sickness may occur, and the eyes have a look of anxiety in them. Usually this passes off, although sickness in exceptional cases may occur at intervals. If the effect travel high the patient may complain of want of breath and appear oppressed with marked *besoin de respirer*. Raising the feet and legs usually relieves this, and a few reassuring words will generally restore the patient's nerve. Injections of caffeine or strychnine in severe attacks may be called for while the head is kept high, and if any pillow is below the pelvis it must be removed. Blood pressure in normal cases is not much depressed, although during such attacks as those described it is considerably lowered, the abdominal veins filling up as the abdominal muscles relax.

The analgesia usually persists for an hour or an hour and

a half, but this varies with the individual and the dose of drug employed.

AFTER EFFECTS AND DANGERS.

Deaths have occurred ; these have usually followed intense dyspnoea with fall of blood pressure, and are assumed to be due to the drug having travelled too high and affected the medulla. Persons who are suffering from shock or are enfeebled by age and pain are most liable to this form of collapse, so that it is usually better to avoid spinal injection for such patients, although when its denial commits them to other and perhaps even greater perils a careful study of the individual case may result in the selection of spinal analgesia for even the most unpromising subjects. It is unsafe to employ this method in the presence of syphilis, or disease affecting the cord and in septic or pyæmic states. Age, with the reservation given above, appears to be no bar, as even babies, it is known, respond well to the method.* Young children are often frightened, and unless reasons exist which render spinal injection desirable it is better to make them unconscious. Serious heart disease and acute febrile states are by some regarded as contra-indications.

As to the sequelæ it is impossible to speak with certainty, as undoubtedly many of the most serious after effects such as persistent and intense headache, vesical paralysis, loss of rectal control, paraplegia, septic spinal meningitis, ocular palsies, which have been recorded, may have been caused by faulty technique. However, really severe headache, persistent vomiting and paresis of the external rectus muscle of the eye, though not common, do occur, and must be borne in mind as possible results.

The mortality rate under spinal analgesia is also difficult to arrive at accurately. In the practice of some Continental surgeons thousands of cases are reported without a death, while in some less favourable statistics the death-rate is stated to be 1 in 200. When we compare such statistics

* The dose for children must be smaller than that given to adults. It is decided by the age and physique of the child.

with those of general anæsthetics, we find much the same discrepancies. In the case of experts, thousands of cases are given with no deaths; but when the general death-rate is arrived at by adding the hospital or other figures, which include the work of skilled and unskilled anæsthetists, the mortality rate becomes less favourable. It is stated by those who have made a special study of such figures that at present the mortality under spinal injection is higher than that under chloroform. Too much importance, however, must not be attached to either set of statistics. It is probable that in really serious cases some deaths will occur whatever method is adopted, and undoubtedly it is the duty of the anæsthetist to select that method which appears to him to hold out the best chances for the patient's immediate comfort and ultimate welfare. Again, the enthusiastic advocates of this method are apt to urge its adoption to avoid sequelæ, which they allege always follow the use of general anæsthetics. Here, again, what has been said above also applies. While dangers and serious discomfort or suffering may follow the use of general anæsthetics, they do not by any means form a necessary part of the evolution of the anæsthetic state any more than those dangers and discomforts rehearsed as possible sequelæ of spinal injection represent the inevitable course of symptoms induced by that method.

In cases when fæcal vomiting is feared, also in diabetics and in cases of advanced renal disease the intra-dural injection of drugs has not fulfilled the promise which was at one time expected. Whether its dangers are less or merely equal to those associated with the use of general anæsthesia in the hands of experts, it is at present impossible to say. It seems probable that local infiltration methods, with or without the use of alkaloids, possibly associated with a form of light narcosis, *e.g.* nitrous oxide and oxygen, will be found to offer the most judicious choice of methods for such complex cases.

Choice of drugs.—Most authorities have ruled out cocaine and alypin as too dangerous. Stovaine, novocain, and tropacocaine may probably be taken as regards reliableness and safety in the order named, although some Continental surgeons have adopted novocain in preference to stovaine,

and have relied upon the use of adrenine in conjunction with it. Those who accept the diffusion theory of the conveyance of the drug along the canal adopt a light as against a denser solution. The writer, however, has no experience of such procedures, and has therefore confined himself to the glucose-stovaine method, the results of which are certainly satisfactory.

Solutions for lumbar injection.—Ampoules for this purpose are supplied with the following strength :

Novocain, 0·15 gramme; adrenine borate, 0·000,325 gramme. This supplies 3 c.c. of a 5 per cent. solution of novocain; of this 2 c.c. to 3 c.c. are injected.

Tropacocaine in 5 per cent. solution, with or without adrenine, is extensively employed.

Stovaine, 5 per cent.; glucose, 5 per cent. These ampoules contain 2 cubic centimetres, of which one is measured off in the syringe, and is the average dose for the adult. This, of course, equals 0·05 gramme (5 centigrammes) of stovaine.

The syringe is filled by inserting the cannula fixed on it into the broken end of the ampoule. The instrument is then turned with the cannula upwards, and tapped in order that any bubbles and all the solution in excess of the exact amount required may be expelled.

ANALGESIA PRODUCED BY FREEZING.

Ether spray * (Sir B. W. Richardson).—The woodcut (fig. 84) explains the simple mechanism of this contrivance.

The analgesia so obtained is confined to the skin, and is very transient. Recovery of sensation when the spray ceases to work is often accompanied by very painful smarting and tingling. The great drawback to the method is that the instruments and skin get thickly coated with ice, which obscures the parts, rendering the use of the knife almost impossible. Further, under ether spray it is difficult to see and secure blood-vessels, and painful to do this when the analgesia has passed off. Unless care be taken, the skin may be so much frozen that a slough like that of frost-bite will follow.

* Richardson recommended anhydrous ether, sp. gr. 0·720, mixed with an equal part of hydride of amyl (rhigolene).

Various agents have been employed which produce a certain degree of analgesia by freezing the tissues upon which they are sprayed. We may mention **methyl chloride** and **ethyl chloride**. **Coryl** is a name given by G. Joubert to ethyl chloride mixed with methyl chloride so as to lower its boiling point from 10° C. to 0° C.; **Anesthyle** is the name given by Dr. Bengué to a mixture of 1 part methyl chloride to 5 ethyl chloride—its use is similar to that of coryl; **Rhigolene**, a product of the distillation of petroleum, was introduced by Richardson, who employed it with ether in his atomising spray.

These substances are kept in tubes with specially con-

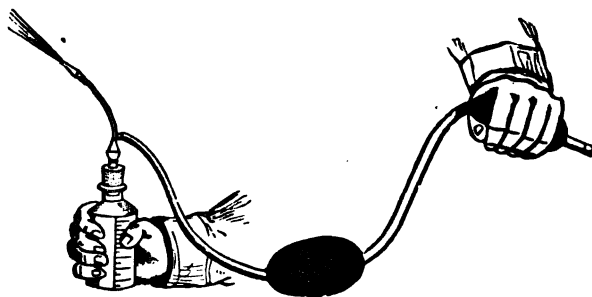


FIG. 84.—Ether spray.

structed stop-cocks, which allow of spraying over the area to be frozen. A large number of drugs have been proposed as local analgesics, but as few have special advantages no further mention need be made of them here.

Faradic currents directed for some minutes through an area of skin or mucous membrane produce some degree of analgesia. At one time this method was in vogue among dentists; it has now fallen into disuse. A recent attempt has been made to revive this plan, improved apparatus being employed, but the success achieved seems to have been so slight as to make it hardly necessary to particularise its features.

CHAPTER XII.

MEDICO-LEGAL ASPECTS OF THE ADMINISTRATION OF ANÆSTHETICS.

LEGALITY OF ANÆSTHETISING PATIENTS.

IN the present state of the law there is no restriction imposed upon any one with regard to the giving of anæsthetics. A further anomaly exists with respect to such powerful drugs as cocaine. Their use undoubtedly requires at least as much acumen as does a general anæsthetic, but unqualified dental practitioners habitually employ cocaine without let or hindrance, and even when the unhappy patient dies as a result of ignorance or lack of skill the offence is dealt with as though the procedure were an absolutely justifiable one, although the result was unfortunate. If, as a medically qualified man, a person gives an anæsthetic carelessly, or reveals complete ignorance, he becomes guilty of malpraxis, since a medical practitioner is expected to know how to carry out this part of his profession. He is also debarred, save under exceptional circumstances, from permitting an unqualified person to give an anæsthetic to his patient, and he is forbidden to give an anæsthetic for an unqualified person such as a "bonesetter," unregistered dentist, and so on. If an unqualified person gives an anæsthetic, or applies an analgesic, and does not represent himself to be a person duly qualified by law, he only comes under legal censure if his patient suffers injury as a result of such an action. These persons are commonly dealt with very leniently, and only suffer if the judge considers that they failed to act with what he considers to be reasonable skill and

knowledge, even although it is recognised by medical men that giving an anæsthetic must be dangerous unless the administrator has received instruction, enjoyed experience, and studied the human frame from the side of physiology and pathology. The unqualified person usually has none of these advantages in his case.

The **administration** of an **anæsthetic** to a **patient** who is not a minor, **against his will**, constitutes an **assault**. When a patient has voluntarily submitted himself to be anæsthetised he may, under the influence of terror, during an early stage of the proceedings, attempt to prevent further narcosis ; he is then not sufficiently guided by his reason, and the administrator is bound, in the patient's interest, to take his own course.

The qualified anæsthetist, like any other medical man, is liable to prosecution for **malpraxis** ; it then rests with him to prove that whatever steps he took were adopted after due consideration and because he believed them to be the best he could follow in the interests of his patient. Such questions as the following might arise : Did the anæsthetist undertake a duty which knowledge, skill, and experience had qualified him to fulfil ? Did he employ the most suitable agent according to his view of the exigencies of the case ? and did he administer it with due skill and by an approved method ? Did he possess himself of all the necessary facts with regard to the patient's bodily condition ? and did he make due allowance for these in the treatment which he pursued ? In the event of an accident of any kind, did he adopt the right and appropriate treatment indicated in such an emergency ? and was this done with due promptitude ?

Anæsthetics have been employed to assist in the **perpetration** of **various crimes** upon the person narcotised. Thus, it is alleged, an anæsthetic may be given without the consent of a person ; or, if it is given with his or her consent to affect a lawful procedure, advantage may be taken of the anæsthetised person's helpless condition to perpetrate a crime.

Can an **anæsthetic** be **administered without consent** ? Firstly, can this be done whilst a person is awake and in full possession of his senses ? Formerly many cases came into the law courts, in which the complainant alleged that a

handkerchief saturated with chloroform was waved before his face and unconsciousness followed *immediately*. This we now know to be an impossibility ; a period of time varying from two to twelve or more minutes must elapse before an individual passes under the influence of chloroform, and during this time fresh supplies of the anæsthetic are needed. Further, chloroform, in most cases, produces so much excitement, that one person would find it a difficult matter to keep the victim sufficiently still to complete the anæsthesia, and could hardly do so without there being both noise and disarrangement of the victim's clothing. Further, unless food is avoided before the anæsthetic is given, vomiting is very liable to occur, and with it a return to consciousness.

It is often alleged by the supposed victim that he, or she, was conscious of what was being done, but was powerless alike to speak or resist. Such statements must be received with the utmost caution. It is true that Péan recorded cases in which patients, though rendered analgesic by ether, retained their consciousness as to what was in course of proceeding. Cases like Péan's must be so exceptional that one is tempted to believe the anæsthetic was administered very imperfectly, and that faith in the assurance of the surgeon did the rest. Snow also admitted the possibility of persons imperfectly chloroformed being conscious and yet powerless to resist. In attempts at criminal violence under an anæsthetic administered without the victim's consent, fear, excitement, and struggles would all be against the possibility of arriving at loss of voluntary power without deep narcosis. It is very doubtful whether a person, be he an expert or not, could narcotise a waking adult against his will unless there existed a very unusual disproportion between the physique of the two individuals. In the case of *R. v. Snarey* the prosecutrix alleged that she had been rendered insensible instantly by something being held over her face upon a handkerchief, and that in that condition she had been violated. This contention could not, in the present state of knowledge, be admitted by experts. However, in a parallel case, that of *White v. Howarth*, the prosecutrix made a similar assertion, and added that she was aware of what was going on, but was unable to resist.

Although the time required to thoroughly anæsthetise a patient is longer when chloroform is used than when ether is employed, yet, from the highly irritating nature of the vapour, ether is less easy to administer to an unwilling patient than is chloroform. And further, ether requires the use of some apparatus more or less excluding air, and hence is less easy to manipulate by those who are not experts. In general it may be affirmed that, if it is not easy to use chloroform for criminal purposes, the employment of ether presents greater difficulty. In a case reported, it was alleged that a burglary was carried out by men who chloroformed the owner of the property as he lay in bed, and then ransacked the premises. The presumption must always be against the truth of such statements. Persons left to guard banks and other places containing valuables have on several occasions affirmed that they were rendered unconscious by chloroform while a robbery was carried out. It is inevitable, in such cases, that the story should be doubted, and indeed the persons uttering it have been shown in some instances to have been the actual depredators.

CAN A PERSON BE ANÆSTHETISED DURING SLEEP?

Dolbeau made careful experiments with reference to this subject, and his conclusions are certainly consonant with the experience of most skilled anæsthetists.

He first attempted to anæsthetise four persons during sleep. Three were awakened during the process. In his second series of cases four persons out of six awakened, and in his third series only three persons awakened out of nine to whom he administered chloroform while they slept. Dr. Turnbull asserts that either chloroform or ether may be given without awakening the subject of the experiment. I have no doubt that chloroform may in some cases be so administered, but am less sure about ether; in either case certain conditions must be present to ensure success. If the patient has been drugged by alcohol, morphine, or is under the influence of grave shock or great fatigue, anæsthesia can be produced without arousing him from stupor. The greatest care, skill, and familiarity with the anæsthetic used might enable an

expert to succeed, and then probably only in the case of a heavy sleeper. Dr. Leonard Guthrie repeatedly tried to chloroform children in their sleep, but he never succeeded.

A further question arises, upon which evidence may be sought, and that is whether, in the event of his escaping capture, it is possible to prove the person attempting to administer an anæsthetic with criminal intent was one skilled in its use. To determine this offers some difficulties. The presence of apparatus, the method in which lint or a handkerchief is folded, or of blistering of the lips and nose from allowing the chloroform to drop upon the face, might offer a clue. If ether is employed we may be sure that the person using it possessed some knowledge, especially if he had used a formal apparatus which was accurately fitted and filled, since ether given by the open method, seldom if ever carries the patient beyond a stage of delirious excitement, unless skilfully handled, and produces bellicose struggles such as would effectually prevent the accomplishment of any criminal design.

Anæsthetics have been given to assist in the committal of ROBBERY, RAPE, and MUTILATION. What has been said above leaves little to add with regard to robbery. Cases have occurred of persons who, it was alleged, were rendered irresponsible for their actions for some weeks, or longer, after taking an anæsthetic. Such instances of temporary insanity are very rare, but may arise among the neurotic, and those whose family history reveals a tendency to mental instability.

In a case in which the writer was asked to give expert evidence, a highly respectable young man was charged with indecent exposure. The defence, which was accepted by the judge as conclusive, was based upon the fact that the defendant's mental poise had been upset as a result of inhaling an anæsthetic. The family history was one of marked mental infirmity.

ATTEMPTED RAPE UNDER ANÆSTHETICS.

Many cases have now been reported in which the prosecutrix has affirmed that a dentist or medical man has violated her person while she was under the influence of an anæsthetic.

So frequent are such charges that the greatest care should be taken in order to ensure the presence of a third person at least within ear-shot and preferably within sight of the administration of the anæsthetic. No administrator of an anæsthetic is safe from having such a charge preferred against him, and if he and his supposed victim were alone it is simply a case word against word. Further, the woman may be *enceinte* at the time of the alleged rape, and may subsequently give birth to an infant, whose parentage she may find it convenient to foist upon the medical man.

But it is not only designing bad women who make accusations: modest, virtuous, and refined gentlewomen have figured in these cases. The cause for this remarkable and deplorable state of things is fortunately not far to seek. Chloroform, ether, possibly also the other carbon compounds employed in producing anæsthesia, nitrous oxide gas, and even cocaine and novocain, possess the property of exciting sexual emotions, and in many cases produce erotic hallucinations. It is undoubted that in certain persons sexual orgasm may occur during the induction of anæsthesia. Women, especially when suffering from ovarian or uterine irritation, are prone to such hallucination, and it is almost impossible to convince them, after their return to consciousness, that the subjective sexual sensation had no objective origin. It is stated that women at their menstrual periods are more prone to erotic hallucinations than at other times, a fact which may be borne in mind. A case cited by Sir B. W. Richardson will illustrate this statement. A young lady had chloroform administered to her by a doctor in the presence of a dentist and of the young lady's mother and father. After a tooth had been extracted, and the patient had become conscious, she steadfastly affirmed that she had been criminally assaulted by the dentist, and to this statement she adhered, although the four persons present in the room strove to disabuse her mind. It is stated that in the case of cocaine and its congeners the hallucination does not develop until some little time after the injection of the drug, and so may not be mentioned until the patient has reached her own home.

In considering the evidence in such cases, the following points need especial attention:—

Nature of the anæsthetic.—Chloroform, ether, and the other members of the carbon anæsthetic series, certainly render persons wholly unable to protect themselves from any personal ill-usage. The body of the anæsthetised patient is, however, rendered utterly flaccid, and is a dead weight. If then there is any question of moving the body—as, for example, from a dental chair, and again back into the chair—it must be remembered that such an undertaking would be exceedingly difficult for one individual, however strong, and could hardly be accomplished without causing much disarrangement of clothing.

On the other hand, if the offence was alleged to have been committed when the patient was under the influence of nitrous oxide gas, it would have to be borne in mind that the effect of this gas is to produce, first muscular rigidity and subsequently violent jactitation. Further, unconsciousness only persists for about half a minute, or, in exceptional cases, a trifle longer, and the patient regains her senses with control over her muscles in a few seconds. This being so, it is exceedingly improbable that even a premeditated and skilfully planned attempt at violation would be successful if made upon a woman under the influence of nitrous oxide gas.

A caution is needed about admitting the evidence of a person only just recovered from an anæsthetic. The following case illustrates this: A dentist appealed to a friend to extract a tooth. Under gas he struggled so violently that the operation was not attempted, but, as he came to, he reproached his friend most bitterly, telling him he had felt the whole pain of the extraction and was even then suffering torture!

Civil actions for damages have occurred in connexion with anæsthetics, in which the patient has sought to recover compensation for such injuries as burns due to hot-water bottles, paralysis of limbs due to faulty posture and even for operations undertaken without full consent of the patient, in which the anæsthetist was held to be an accessory. It is obvious, however, that unless he made himself personally responsible, the anæsthetist would not be mulcted for any alleged torts of his surgical confrère. It is, however, his duty to exercise a general supervision of the patient's condition, posture, and so on, although from the

very nature of things it is the surgeon who would decide the position of the patient and the extent and nature of the operation undertaken. This would not, however, protect the anæsthetist in the event of an illegal operation being performed (see below).

DEATH UNDER AN ANÆSTHETIC.

It becomes requisite to decide whether the death was suicidal, accidental, or followed an anæsthetic given by a person other than the deceased; and then whether the individual who actually administered the anæsthetic was competent to do so. Chloroform is frequently used as an anodyne, and many deaths have resulted from accidents, such as the soaking of the patient's pillow with chloroform. The presence of a phial near the corpse might point to self-administration. Ether is not used similarly, and is not commonly selected by suicides, although ether drinking is practised in some districts. One death from nitrous oxide gas, under similar circumstances, is reported from America. A dentist, whilst under the influence of drink, placed himself in his chair and, turning on the gas, held the face-piece over his mouth and nose. In the morning he was found dead, and the gasometer empty. A somewhat similar case has occurred in England.

It is important to carefully search for evidence as to *how* the anæsthetic was administered, as this may determine whether it was done *secundum artem* or unskilfully.

The **inquiry** into a **death** supposed to be from an **anæsthetic** commences with the question—Was death due to the anæsthetic, to hæmorrhage, shock, exhaustion, or to some other complication following the surgical operation? The mode of death due to chloroform, ether, and other agents, is described under the heading *chloroform*, etc.

The consent of the patient, or of his guardians if a minor, must be established unless it can be shown that the operation and the anæsthetic were necessary to save life, and were undertaken under the stress of an emergency which precluded delay. The more difficult question arises when the patient who is desperately ill declines an anæsthetic through

fear, while his friends desire that every step which is necessary to give him a chance of life, shall be carried out. It is unquestionable that unless the patient's mental condition is obviously not such as to make him capable of a responsible decision, his wishes must be respected. If, however, he is for the moment *non compos mentis* his position in refusing the anæsthetic and operation is akin to that of a would-be suicide and warrants some effort to save his life even against his will.

The CHOICE of the ANÆSTHETIC would have to be JUSTIFIED: thus, were chloroform given for a simple tooth extraction in lieu of the safer agent—nitrous oxide gas—and were the patient to succumb, the administrator would have to explain why he selected the most dangerous agent and what physical conditions existed which justified him in his choice.

All anæsthetics are dangerous. In the hands of one skilled in their use this danger is minimised; but, whatever may be individual uses and opinions, the general consensus of belief places anæsthetics in the following order of safety: nitrous oxide gas when used for short operations; ether: ethyl chloride; chloroform. Other substances are not used sufficiently often to make statistics reliable, but the following table gives a rough estimate of their danger.*

TABLE SHOWING DEATH-RATE UNDER THE VARIOUS ANÆSTHETIC BODIES.†

	Deaths.	Administrations.
Chloroform (Coles, Virginia)	53	152,260
„ (Richardson)	1	2,500 to 3,000
„ Baudens (during Crimean War)	1	10,000
„ War of Secession	1	11,448
„ Gurlt (Reports in Germany, 1895 and 1896)	29	34,401
„ Julliard (Geneva)	161	524,507

* No great stress can be laid upon such figures, as in many cases a death occurred very early in the career of an anæsthetic, and this rendered further trials of it inadvisable.

† The Report of Anæsthetics Committee, Brit. Med. Assn., July 1900, gives 18 chloroform deaths in 13,393. These are classified as 3 due wholly to chloroform, 4 principally to it and 11 doubtful. Under ether 6 deaths in 4,595 cases, but none entirely due to the anæsthetic.

	Deaths.	Administrations.
Ether (Andrews *)	1	23,204
„ Julliard (Geneva)	1	14,987
„ Lee (Chicago)	4	92,816
„ Gurlt (German Hospitals, 1895 and 1896)	3	13,008
Nitrous Oxide Gas	1	100,100
Ethyl Chloride	1	13,000
Amylene	2	238
Hydrobromic Ether	2	600
A.C.E. mixture, No. not ascertainable †		
Methylene mixture	1	5,000

It must be added that Scotland presents a series of statistics much more favourable to chloroform; thus, out of 36,500 administrations at the Edinburgh Infirmary during ten years, only one death has been recorded. Inquiries recently made have revealed that several deaths from chloroform have occurred at the various surgical centres of Scotland, so that the above estimate can no longer be taken as a reliable statement of the death-rate from chloroform.‡

Dr. McEwen gives his own results at Glasgow (computed, not recorded) as 11,886 cases of anæsthetics, 500 of which were ether cases. He makes various deductions from his total and regards 10,000 with one death as his chloroform record. Sir George Macleod mentions 15,000 cases with one death, and Dr. Buchanan 9,000 with one death. This gives the total of 34,000 with three deaths, or one in 11,000 about, for three leading Scotch surgeons. This estimate cannot be taken as representing accurately the death-rate under chloroform in Scotland at the present time.

QUESTIONS OF RESPONSIBILITY.

These arise when the patient dies under an anæsthetic, and may involve the question as to whether the most suitable

* Probably too low an estimate.

† Richardson states erroneously that no death has occurred under A.C.E. mixture. Dr. Reeve of Dayton, Ohio, reports three deaths, and several others have been recorded.

‡ No Coroner's Inquest is held in Scotland upon "Deaths under Chloroform," hence their occurrence does not obtain publicity.

anæsthetic was employed by the best method. Sometimes a patient refuses one anæsthetic, preferring another ; here the administrator clearly cannot shirk responsibility, but must give that agent which he deems best if actual danger is involved in deferring to the wish of the patient. In the converse case, when death occurs during the administration of an anæsthetic which the patient declined to take until persuaded, cajoled, or forced into so doing, the anæsthetist would have to show that his special knowledge guided him in making his selection, which, although it led to a fatal result, was, in point of fact, the best choice he could make in the patient's interests. In the employment of a new or untried anæsthetic, very grave responsibility would rest with the administrator unless he very fully and clearly explained the possible results, and obtained the patient's consent to the trial.

A question which we have not yet fully considered arises—Who, in the eye of the law, is qualified to administer an anæsthetic? At present some uncertainty exists upon the point, owing to discretionary power being left to the operator to assume the so-called responsibility of the anæsthetic. Thus nurses, students, butlers, coachmen, dispensers, and various unqualified persons have been frequently permitted to give the anæsthetic, or, as the phrase is, "keep it going," while the surgeon, besides operating, is supposed to exercise a general supervision over the administrator's proceedings. If any accident happened the death certificate would have to be signed by the surgeon, and the Coroner's Court might admit the principal's evidence. It cannot be doubted that, to give any individual an anæsthetic subjecting him to a minimum of danger is all one person can do, and can only be accomplished by those specially instructed and experienced in the use of anæsthetics. Were an action for damages raised upon a death occurring under the above-named circumstances, there is little doubt that the persons proceeded against would be heavily mulcted, since nothing short of the utmost emergency could justify the proceeding.

The more stringent view now taken by the General Medical Council with respect to "covering" renders the position of a qualified medical man who allows an unqualified person to assist him by administering an anæsthetic an equivocal one.

Unless it could be shown that the aid of a second qualified medical practitioner could not be obtained or that delay was detrimental to the patient, the question of "covering" would arise, and the medical man would incur the risk of having his name struck off the Medical Register. The similar case, that in which a medical man has given an anæsthetic for an unqualified person who performs the operation, has been decided by the General Médical Council ; the name of the medical man being struck off the Medical Register.

Recently an action for malpraxis was brought in a colonial court against a medical man who had administered chloroform to a patient with a fatal result. The question rested upon whether the anæsthetic was rightly and skilfully given, and, this being taken as proved, the court decided the case in the medical man's favour.

In another case the medical man administered the anæsthetic (chloroform) without assistance, and proceeded to operate. The patient however, died, and an action for damages was brought and eventually decided in the medical man's favour. The line of defence adopted was (1) the medical man was duly qualified ; (2) chloroform was necessary ; (3) the operation being slight—moving a joint—the presence of a second doctor was unnecessary ; (4) all was done which experience and knowledge demanded ; (5) the death was unavoidable, and not due to carelessness or want of skill. Expert witnesses were called for the defence to show that the anæsthetic used was a suitable one, and that it was properly administered. When a medical man **gives an anæsthetic and operates single-handed** as in the case cited, he undoubtedly places both himself and his patient in a dangerous position. Unless emergency can be pleaded it seems probable that the question of justification would be decided upon the merits of each case and upon the status and recognised skill of the practitioner. It is not a wise procedure, however, and too often courts disaster.

SHOULD DENTISTS GIVE ANÆSTHETICS?

How far dentists practising with or without the L.D.S. diploma are legally justified in administering anæsthetics is

a moot point. Many hold that the L.D.S. confers a right to the administration of nitrous oxide gas, but no other form of anæsthetic. In the United Kingdom, I believe, no trial case has been contested. The ground for this affirmation that licentiates in dental surgery possess such a right has no legal basis, but has grown out of the belief that the use of nitrous oxide gas is part and parcel of the dentist's calling, and that so he has a right to employ it. This, however, applies with equal force to all registered dental practitioners. Probably the issue would rest, in the present ambiguous state of the law, more upon the experience and recognised skill of the person administering the anæsthetic than upon the nature of his qualification. If it be shown that a registered dental practitioner, after two or three thousand successful administrations, met with an accident, in spite of all due care and precaution, he would probably be in a better position than would a practitioner with a diploma who met with a fatality, presumably through maladroitness, if it were proved that he had never obtained a practical experience in giving anæsthetics.

In any case, a person would be open to grave censure, if not liable for malpraxis, were he to undertake the administration of an anæsthetic, and operate single-handed, unless it could be shown that to do so was a necessity, no help being available. Dentists on the Register are of course under the same regulations as regards covering as those obtaining in the case of a medical man.

LEGAL RESPONSIBILITIES OF ANÆSTHETISTS.

It has been made a subject of much debate—with whom rests the responsibility of the choice of the anæsthetic, with the surgeon who operates, or with the anæsthetist who gives the anæsthetic? Clearly this must depend entirely upon the understanding which exists between the two. If the anæsthetist is called in, as an expert, to decide what anæsthetic is best for any given patient, his must be the sole responsibility; while if an anæsthetist is present simply as an assistant to the surgeon to give in the best possible way an anæsthetic which is named by the latter, his responsibility can extend

only so far as the actual administration is concerned. If the two disagree, the surgeon, insisting upon an anæsthetic which the anæsthetist conscientiously believes will jeopardise the patient's life, cannot cover the anæsthetist, and the latter has but one course to adopt, namely, to retire from the case. As, however, the experience of the surgeon may equal or exceed that of the anæsthetist, especially if the patient is the former's, to retire from the case is a grave step for any anæsthetist to adopt, and could only be justified in most extreme cases. It is best when doubt exists that a consultation between the surgeon and the anæsthetist should be held and the questions of choice of anæsthetic and method should be discussed deliberately from the two points of view. The fact that the anæsthetist is a duly qualified medical man and so is personally responsible for his professional procedure and skill must not be lost sight of, and it precludes him from claiming exemption from blame if the patient suffers from the effects of the anæsthetic, even though the surgeon professes to accept full responsibility.

COVERING.

It has been decided by the General Medical Council that any medical man who gives anæsthetics for a person who does not, in fact, possess the right to practise as a dentist is in the eyes of the Council guilty of the offence of "covering." Similarly, giving anæsthetics for unqualified bonesetters or unregistered surgeons has been definitely pronounced to constitute an act of "covering," and so carries the penalty of that offence. The kindred case of a qualified medical man inviting an unqualified assistant to give an anæsthetic has frequently arisen. As has been pointed out above, unless it can be shown that the help of a second qualified practitioner could not be obtained the qualified practitioner might be liable to an indictment for "covering."

ANÆSTHETICS FOR ILLEGAL OPERATIONS.

How far, in the eyes of the law, an anæsthetist would be regarded as an accomplice to the operator is at present undetermined by judicial decisions. In the event of the

anæsthetist becoming acquainted with the nature of the proposed operation before the anæsthetic was given he would certainly be incriminated if he then assisted in the performance of the operation by administering the anæsthetic. Whilst it is not the business of the anæsthetist to inquire into the nature of any operation, or to criticise the way in which it is performed, he should make himself acquainted with the fullest details of the case if he has his suspicions aroused. When any doubt is present in his mind as to the legality of the operation, or as to the *bona fides* of the person conducting the case, he will do wisely to retire from it, as his presence gives his tacit consent to the operation, and would probably place him in the same position as the operator should legal prosecution follow. It need hardly be pointed out that the anæsthetist shares in no way the legal responsibility as to the advisability of an operation, the manner in which it is performed, its success or failure, save and except in so far as these may be involved in the manner in which he has conducted the administration of the anæsthetic. An exception to this arises when the anæsthetist becomes acquainted beforehand with any facts which make it evident that the operation is a fraud, or undertaken to obtain money by false pretences, and is not one which would be performed by any recognised authorities upon the subject. Under such circumstances the anæsthetist has but one course open to him, viz. to retire from the case.

DEATH FROM NITROUS OXIDE GAS.

The deaths which have occurred when the patient had inhaled or was inhaling this gas cannot be imputed to any specific action it exercised. In some cases heart failure occurred upon the patient's resuming consciousness *before the operation was completed*, and in others respiration was interfered with by gags slipping, and setting up laryngeal spasm. Unquestionably there is danger if the patient is allowed to feel pain, especially in operations upon the fifth pair of nerves; but little, if any, when the gas is given fully, and the operator warned to desist before consciousness returns. In one case an elderly lady died under this anæsthetic.

She was wearing extremely tight corsets, her heart was diseased, and her stomach contained food. The gas was, moreover, administered twice. It has been stated* that when nitrous oxide and oxygen are given together acute dilatation of the heart takes place, and fatal results follow if chloroform is given after this mixture.

The post-mortem appearances are simply those of death from syncope, or of death from asphyxia.

DEATH FROM ETHER.

Ether, when swallowed, gives the following symptoms. The patient is lethargic or comatose, breathing slowly, deeply, and with stertor; the skin is pale and cold, and covered with clammy sweat. The exposed mucous membranes will be purplish; the face livid; the pulse quick, soft, small, and compressible. Complete muscular relaxation gives the body a flaccid, doughy feel. The eye is fixed and glassy, and usually smeared with a thick film of mucus, the pupils are dilated, and insensitive to light. The body temperature is depressed several degrees below the normal.

The symptoms detailed may be brought on in from three to five minutes. Six drachms to an ounce are necessary to produce narcotism when swallowed. Ether, when swallowed, has not caused death in the human subject (Taylor). Orfila, experimenting upon dogs, found the mucous membrane of the stomach of a black-red colour, acutely inflamed by a lethal dose of ether. The duodenum was also red and inflamed, and the heart contained black blood which was partly coagulated.

If the vapour of ether has been inhaled, a much smaller dose suffices to produce death than when liquid ether is swallowed. The symptoms and appearances of persons dying as a result of ether inhalation will differ according as the ether has caused respiratory or circulatory failure. In cases of acute pulmonary œdema the lung symptoms will predominate, while cerebral hæmorrhage occurring under ether will give the characteristic symptoms associated with the brain lesion.

* *Proc. Soc. Anæsth.*, vol. ii., p. 179 (see above, p. 123, Case III.).

Post-mortem appearances.—If examined within twenty-four hours after death the brain, lungs, liver, spleen, or kidneys, upon being cut, give a strong ethereal smell. The blood is dark and thick, although still fluid. The lungs are congested posteriorly, and filled with aërated spumous fluid in front (Taylor). The bronchial mucous membrane is reddened from injection throughout its entire extent. The cerebral and spinal vessels are found congested, and the meninges stained.

The detection of ether by analysis.—Ether in liquid may be distilled from the stomach contents, and led through a glass tube containing asbestos moistened by a mixture of sulphuric acid and saturated solution of bichromate of potash. The asbestos turns green.

Its odour is also characteristic; ether burns with a smoky yellow flame; it is only slightly soluble in water.

The tissues.—In recent examinations the odour is characteristic. Since but little ether is absorbed by the blood, and of this little some is converted into aldehyde (Taylor), it is almost impossible to separate ether by distillation from the blood or the solid tissues.

DEATH FROM POISONING BY CHLOROFORM.

This may occur through inhaling the vapour or drinking the fluid. In the latter case the individual if examined before death will be comatose, breathing stertorously, with slow, shallow respirations. The skin will be cold and blanched, the face livid, the lips ashen in hue, the pulse imperceptible, and the pupils may be widely dilated, but insensitive to light. Muscular flaccidity is present, but epileptiform convulsions often occur.

Post-mortem appearances.—In cases of death from chloroform the appearances reported vary very much, and this is probably due to the confusion present in the minds of many persons concerning the connexion of cause and effect. Thus death from asphyxia, fear, shock, and so on, may be attributed to chloroform; furthermore, the necropsies are seldom made soon enough to be of any value, while sufficient note is seldom taken of the degree of narcosis in which death occurred.

We should expect the cadaveric appearances presented in the first degree of narcosis to differ widely from those found in later degrees, and yet in but few records have I been able to find any information bearing directly upon this point.

In the earlier degrees chloroform congests the vessels of the brain and cord, and so this condition, although inconstant, is sometimes found.

The lungs are usually deeply congested, the heart empty, flaccid, or containing a little fluid blood. In some cases the right heart is full; even to distention, of dark fluid blood (asphyxia). The blood remains fluid, it is very dark, and is said occasionally to contain bubbles of gas (Taylor). Snow, analysing thirty-four cases, describes visceral engorgement, but in some instances he found the lungs normal. Casper denies that any of the features pictured above are pathognomonic of chloroform poisoning. When the drug is swallowed it produces gastro-enteritis, and pathological appearances resulting from this would be seen post-mortem. The appearance of the viscera in "delayed" chloroform poisoning (acidosis), as in the case of delayed ether poisoning, are not entirely characteristic, since similar appearances are found as the result of septic and other conditions. The liver, kidneys and heart are often friable, the cells are fatty, and the gastro-intestinal tract is congested. Acetone, diacetic or β oxybutyric acids may at times be recognised in the urine.

Detection of chloroform.—The odour very soon passes off. Dr. Taylor failed to detect any in the blood half an hour after administration. Analysis of the blood also fails to reveal any evidence after half an hour.

Analysis of the tissues.—The substance supposed to contain chloroform is placed in a flask, one end of which is in a hot-water bath, the other communicating with a tubulure which is heated by a flame. The bath is raised to 160° F., while the tube is heated to redness. Chloroform vapour driven off by the heat of the water bath is split up as it traverses the tube, hydrochloric acid and chlorine being set free. The vapour reddens blue litmus, precipitates solutions of nitrate of silver, and liberates iodine from iodide of potassium, and this is tested in the usual way—with starch paper. The most

accurate method of obtaining a quantitative analysis is that of Mr. A. Vernon Harcourt.

SELF-INDULGENCE IN ANÆSTHETICS.

A "habit" has been unhappily created for most forms of anæsthetics. Thus, some persons become addicted to self-administration of chloroform; others to that of ether; others again to that of chloral hydrate; while cocaine also has its victims. It is not within the scope of the present work to describe the proper modes of treating the slaves of this unfortunate vice, but merely to draw attention to them, that medico-legal questions arising out of such depraved practices may receive due notice. Nitrous oxide gas, although presenting greater difficulties to self-administration, has yet led some weak-principled persons to practise self-induction of anæsthesia by its aid.

The possibility of the subject of an inquiry—in any case of supposed suicide or murder by anæsthetics—being an habitué of one of them, should not be allowed to drop out of mind.

INSANITY FOLLOWING THE ADMINISTRATION OF ANÆSTHETICS.

Among persons predisposed to insanity the administration of anæsthetics may, in certain rare cases, determine an attack of mania. "It is the fact of the temporary disturbance of function, and not the means by which this is produced, which is of most importance" (Savage). It is stated, upon the high authority of Sir George Savage, that chloroform, ether, nitrous oxide gas, or indeed any anæsthetic, is capable of so interfering with brain functions, that the delirium of commencing narcosis may become reproduced upon the patient's recovering from the sway of the anæsthetic, and may either persist as intractable mania, or pass off after expending its violence in a sharp but transient maniacal seizure. This liability was also noted in 1865 by various speakers at the meeting of the Superintendents of American Institutions for the Insane, at least as far

as chloroform and ether were concerned. The possibility of such a result ensuing upon the administration of an anæsthetic to a person either highly neurotic, or coming from a family in which insanity has been developed, should be borne in mind when such individuals are examined with a view to ascertain their fitness for anæsthetisation. The suggestion that such persons should be treated with spinal or local analgesia cannot be considered satisfactory. Mania is recognised as a possible result of these methods, and those who have had much experience warn us against employing them for neurotic and highly nervous patients.

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